**2024-1003, 2024-1018**

IN THE

# United States Court of Appeals

**FOR THE FEDERAL CIRCUIT**

GEOSCOPE TECHNOLOGIES PTE. LTD.,

*Plaintiff-Appellant,*

—v.—

GOOGLE LLC, APPLE INC.,

*Defendants-Appellees.*

APPEALS FROM THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF VIRGINIA
IN NOS. 1:22-CV-01331-MSN-JFA, 1:22-CV-01373-MSN-JFA,
JUDGE MICHAEL S. NACHMANOFF

## BRIEF FOR PLAINTIFF-APPELLANT

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GOOGLE EXHIBIT 1030
Google v. Geoscope
IPR2023-01212

## U.S. PATENT NO. 8,406,753 - CLAIM 1

1. A method of determining the location of a mobile device in a geographic region comprising the steps of:

   (a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;

   (b) generating one or more sets of grid points for said calibration data;

   (c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;

   (d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;

   (e) selecting a set of grid points as a function of a predetermined criteria; and

   (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points.

## U.S. PATENT NO. 7,561,104 - CLAIM 1

1. A method for determining a location of a mobile station, comprising:

   providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a first transmitter and a second transmitter;

   collecting observed network measurement data including a first signal characteristic from said first transmitter and a second signal characteristic from said second transmitter;

   determining which of said first and second signal characteristics has a greater magnitude;

   modifying said observed network measurement data using the greater magnitude signal characteristic; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**U.S. PATENT NO. 7,561,104 - CLAIM 2**

2. The method of claim 1 wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

# UNITED STATES COURT OF APPEALS FOR THE FEDERAL CIRCUIT

## CERTIFICATE OF INTEREST

**Case Number** 2024-1003

**Short Case Caption** Geoscope Technologies Pte. Ltd. v. Google LLC

**Filing Party/Entity** Appellant: Geoscope Technologies Pte. Ltd.

**Instructions:**

1. Complete each section of the form and select none or N/A if appropriate.
2. Please enter only one item per box; attach additional pages as needed, and check the box to indicate such pages are attached.
3. In answering Sections 2 and 3, be specific as to which represented entities the answers apply; lack of specificity may result in non-compliance.
4. Please do not duplicate entries within Section 5.
5. Counsel must file an amended Certificate of Interest within seven days after any information on this form changes. Fed. Cir. R. 47.4(c).

I certify the following information and any attached sheets are accurate and complete to the best of my knowledge.

Date: 10/16/2023

Signature: /s/ Timothy K. Gilman

Name: Timothy K. Gilman

| **1. Represented Entities.** Fed. Cir. R. 47.4(a)(1). | **2. Real Party in Interest.** Fed. Cir. R. 47.4(a)(2). | **3. Parent Corporations and Stockholders.** Fed. Cir. R. 47.4(a)(3). |
|---|---|---|
| Provide the full names of all entities represented by undersigned counsel in this case. | Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities.<br><br>☑ None/Not Applicable | Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities.<br><br>☐ None/Not Applicable |
| Geoscope Technologies Pte. Ltd. | | Hong Kong Technologies Group Limited |
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☐ Additional pages attached

**4. Legal Representatives.** List all law firms, partners, and associates that (a) appeared for the entities in the originating court or agency or (b) are expected to appear in this court for the entities. Do not include those who have already entered an appearance in this court. Fed. Cir. R. 47.4(a)(4).

☐ None/Not Applicable ☐ Additional pages attached

| | | |
|---|---|---|
| Stroock & Stroock & Lavan LLP | Christopher M. Gerson | Natalie D. Lieber |
| Gregory R. Springsted | Ryan J. Singer | Alexandra J. Cho |
| Spotts Fain P.C. | Christopher W. Bascom | John M. Erbach |

**5. Related Cases.** Other than the originating case(s) for this case, are there related or prior cases that meet the criteria under Fed. Cir. R. 47.5(a)?

☑ Yes (file separate notice; see below) ☐ No ☐ N/A (amicus/movant)

If yes, concurrently file a separate Notice of Related Case Information that complies with Fed. Cir. R. 47.5(b). **Please do not duplicate information.** This separate Notice must only be filed with the first Certificate of Interest or, subsequently, if information changes during the pendency of the appeal. Fed. Cir. R. 47.5(b).

**6. Organizational Victims and Bankruptcy Cases**. Provide any information required under Fed. R. App. P. 26.1(b) (organizational victims in criminal cases) and 26.1(c) (bankruptcy case debtors and trustees). Fed. Cir. R. 47.4(a)(6).

☑ None/Not Applicable ☐ Additional pages attached

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# UNITED STATES COURT OF APPEALS
# FOR THE FEDERAL CIRCUIT

## CERTIFICATE OF INTEREST

**Case Number** 2024-1018

**Short Case Caption** Geoscope Technologies Pte. Ltd. v. Apple Inc.

**Filing Party/Entity** Appellant: Geoscope Technologies Pte. Ltd.

**Instructions:**

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2. Please enter only one item per box; attach additional pages as needed, and check the box to indicate such pages are attached.
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I certify the following information and any attached sheets are accurate and complete to the best of my knowledge.

Date: 10/16/2023

Signature: /s/ Timothy K. Gilman

Name: Timothy K. Gilman

| **1. Represented Entities.** Fed. Cir. R. 47.4(a)(1). | **2. Real Party in Interest.** Fed. Cir. R. 47.4(a)(2). | **3. Parent Corporations and Stockholders.** Fed. Cir. R. 47.4(a)(3). |
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| Provide the full names of all entities represented by undersigned counsel in this case. | Provide the full names of all real parties in interest for the entities. Do not list the real parties if they are the same as the entities.<br><br>☑ None/Not Applicable | Provide the full names of all parent corporations for the entities and all publicly held companies that own 10% or more stock in the entities.<br><br>☐ None/Not Applicable |
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☑ None/Not Applicable ☐ Additional pages attached

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# TABLE OF CONTENTS

**Page**

STATEMENT OF RELATED CASES ..... 1

STATEMENT OF JURISDICTION ..... 2

PRELIMINARY STATEMENT ..... 2

STATEMENT OF THE ISSUES ..... 5

STATEMENT OF THE CASE ..... 6

A. Procedural History ..... 6

B. Factual Background ..... 8

1. Andrew Corporation and CommScope ..... 8

2. Geolocation of Mobile Devices ..... 10

3. The Inventions of the Appealed Patents ..... 13

SUMMARY OF THE ARGUMENT ..... 26

ARGUMENT ..... 27

I. STANDARD OF REVIEW ..... 27

II. APPLICABLE LAW ..... 29

III. THE CLAIMS OF THE ’753 PATENT ARE PATENT-ELIGIBLE ..... 32

A. Step One: The Claims of the ’753 Patent Recite a Specific Improvement to Geolocation Technology that is Not Abstract ..... 33

1. The district court improperly overgeneralized the ’753 Patent claims by ignoring its adopted claim constructions ..... 34

2. The ’753 Patent claims are directed to a specific improvement to geolocation technology that uses novel data structures to solve a problem in the field ..... 40

B. Step Two: The Claims of the ’753 Patent Recite an Inventive Concept .....51

IV. THE “NON-UNIFORM GRID POINTS” CLAIMS OF THE ’104 PATENT FAMILY ARE PATENT-ELIGIBLE .....55

CONCLUSION .....62

# TABLE OF AUTHORITIES

**Page(s)**

## Cases

*Aatrix Software, Inc. v. Green Shades Software, Inc.*,
882 F.3d 1121 (Fed. Cir. 2018) .....28, 52

*Adasa Inc. v. Avery Dennison Corp.*,
55 F.4th 900 (Fed. Cir. 2022) .....*passim*

*Alice Corporation Pty. Ltd. v. CLS Bank International*,
573 U.S. 208 (2014).....*passim*

*Amgen Inc. v. Hoechst Marion Roussel, Inc.*,
314 F.3d 1313 (Fed. Cir. 2003) .....38

*Bascom Global Internet Services, Inc. v. AT&T Mobility LLC*,
827 F.3d 1341 (Fed. Cir. 2016) .....31, 32, 54

*Berkheimer v. HP Inc.*,
881 F.3d 1360 (Fed. Cir. 2018) .....54

*CardioNet, LLC v. InfoBionic, Inc.*,
955 F.3d 1358 (Fed. Cir. 2020) .....30, 49

*Cellspin Soft, Inc. v. Fitbit, Inc.*,
927 F.3d 1306 (Fed. Cir. 2019) .....52, 53, 54

*Chamberlain Group, Inc. v. Techtronic Industries Co.*,
935 F.3d 1341 .....49

*Conner v. Cleveland County, North Carolina*,
22 F.4th 412 (4th Cir. 2022) .....27

*Cooperative Entertainment, Inc. v. Kollective Technology, Inc.*,
50 F.4th 127 (Fed. Cir. 2022) .....28, 54

*Core Wireless Licensing S.A.R.L. v. LG Electronics, Inc.*,
880 F.3d 1356 (Fed. Cir. 2018) .....45

*CosmoKey Solutions GmbH & Co. KG v. Duo Security LLC*,
15 F.4th 1091 (Fed. Cir. 2021) .....28

*DDR Holdings, LLC v. Hotels.com, L.P.*,
773 F.3d 1245 (Fed. Cir. 2014) .....46

*Diamond v. Diehr*,
450 U.S. 175 (1981).....30, 45, 47, 58

*Enfish, LLC v. Microsoft Corp.*,
822 F.3d 1327 (Fed. Cir. 2016) .....*passim*

*Finjan, Inc. v. Blue Coat Sytems, Inc.*,
879 F.3d 1299 (Fed. Cir. 2018) .....34, 35

*Koninklijke KPN N.V. v. Gemalto M2M GmbH*,
942 F.3d 1143 (Fed. Cir. 2019) .....50

*Markman v. Westview Instruments, Inc.*,
52 F.3d 967 (Fed. Cir. 1995) (en banc) .....17, 34

*McRO, Inc. v. Bandai Namco Games America Inc.*,
837 F.3d 1299 (Fed. Cir. 2016) .....39

*MyMail, Ltd. v. ooVoo, LLC*,
934 F.3d 1373 (Fed. Cir. 2019) .....27, 28, 34, 35

*Packet Intelligence LLC v. NetScout Systems, Inc.*,
965 F.3d 1299 (Fed. Cir. 2020) .....48, 50

*Pulte Home Corporation v. Montgomery County*,
909 F.3d 685 (4th Cir. 2018) .....28

*Sanderling Managementt Ltd. v. Snap Inc.*,
65 F.4th 698 (Fed. Cir. 2023) .....35

*Sequoia Technology, LLC v. Dell, Inc.*,
66 F.4th 1317 (Fed. Cir. 2023) .....35

*SRI International, Inc. v. Cisco Systems, Inc.*,
930 F.3d 1295 (Fed. Cir. 2019) .....30, 46, 49, 50

*Thales Visionix Inc. v. United States*,
850 F.3d 1343 (Fed. Cir. 2017) .....30, 47, 50

*Uniloc USA, Inc. v. LG Electronics USA, Inc.*,
957 F.3d 1303 (Fed. Cir. 2020) .....31, 43, 46

*V-Formation, Inc. v. Benetton Group SpA*,
401 F.3d 1307 (Fed. Cir. 2005) .....23

*Visual Memory LLC v. NVIDIA Corporation*,
867 F.3d 1253 (Fed. Cir. 2017) .....31

**Statutes**

28 U.S.C. §§ 1291 & 1295(a)(1).....2

28 U.S.C. §§ 1331 & 1338.....2

35 U.S.C. § 101 .....*passim*

## STATEMENT OF RELATED CASES

Pursuant to Federal Circuit Rule 47.5, Plaintiff-Appellant Geoscope Technologies Pte. Ltd. ("Geoscope") states that no other appeal in or from either *Geoscope Technologies Pte. Ltd. v. Google LLC*, Civil Action No. 1:22-cv-01331-MSN (E.D. Va.) ("Google Action") or *Geoscope Technologies Pte. Ltd. v. Apple Inc.*, Civil Action No. 1:22-cv-01373-MSN (E.D. Va.) ("Apple Action") was previously before any appellate court. Although the appeals from the Google and Apple Actions were initially docketed separately, they have been consolidated. ECF No. 11.

There are four pending related petitions for *inter partes* review ("IPR") that were filed before final judgment, challenging the four patents at issue here:

- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01209 (filed August 10, 2023)
- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01210 (filed August 10, 2023)
- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01211 (filed August 10, 2023)
- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01212 (filed August 9, 2023)

There are two additional pending related IPR petitions that were filed after final judgment and after Geoscope filed its notice of appeal, challenging two of the patents at issue here:

- *Apple Inc. v. Geoscope Technologies Pte. Ltd.*, IPR2024-00031 (filed October 31, 2023)
- *Apple Inc. v. Geoscope Technologies Pte. Ltd.*, IPR2024-00032 (filed October 31, 2023)

Additionally, there are two pending related IPR petitions challenging two patents that were asserted below but are not at issue here:

- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01213 (filed August 9, 2023)
- *Google LLC v. Geoscope Technologies Pte. Ltd.*, IPR2023-01214 (filed August 9, 2023)

None of these IPR proceedings has reached a decision on institution.

## STATEMENT OF JURISDICTION

This is an appeal from final judgments of the District Court for the Eastern District of Virginia, the Honorable Michael S. Nachmanoff presiding, entered on October 5, 2023 in the Apple Action and on October 6, 2023 in the Google Action. The district court had jurisdiction pursuant to 28 U.S.C. §§ 1331 & 1338. Geoscope's notice of appeal was filed on September 25, 2023 in both actions. This Court has jurisdiction under 28 U.S.C. §§ 1291 & 1295(a)(1).

## PRELIMINARY STATEMENT

The four patents-at-issue claim specific technological solutions to technological challenges in geolocation. Geolocation involves using signal measurements to locate a user device. As opposed to using dedicated satellite signals like GPS for geolocation, the patents-in-suit—as construed—address a specific kind

of geolocation using "network measurement reports," which are reports used in cellular networks containing measurements of cellular signals. These are not signals that were intended for geolocation. Rather, they are "signals of opportunity"—signals intended for other purposes, like telephony, which could be repurposed for geolocation. But technological challenges existed with this approach to geolocation, such as sparsity of reference points—cell towers may be few and far between—and the irregular propagation of signals in the presence of environmental obstructions such as hills or buildings.

Andrew Corporation—a communications technology company acquired by CommScope, Inc. for $2.6 billion in 2007—overcame these technological challenges through the inventions of the patents-at-issue, which all claim priority to a provisional application filed in February 2007. These patents were later spun-off to Plaintiff-Appellant Geoscope. The core of the inventions included "grid points," unconventional data structures recited in every claim at issue. As construed and as recited in the claims, these were not conventional grids, but rather dynamic data structures whose properties—*e.g.*, geographic location and boundaries—were determined *as calibration data was acquired*, and then associated with representative signal data that characterized the area within those boundaries. They looked nothing like any conventional conception of grids or grid points:

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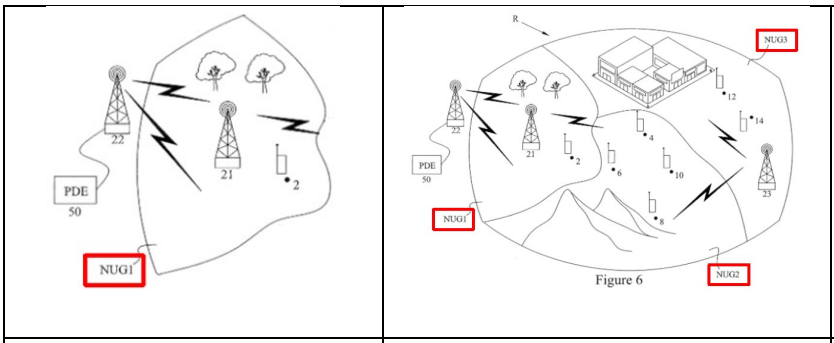
|  | | |
| "grid point" as claimed | three "grid points" mapping a region | conventional grid |

The claims require these grid points to be generated dynamically from the measured calibration data, and the specification describes at length how to do so. By generating these novel grid points as new data was measured, the inventions helped to fill in the "map" between cell towers, so that geolocation could be faster, require fewer resources, and be more accurate—concrete technological benefits. The claims of the '104 Patent Family went further, and added corrections for the differential propagation of signals outdoors (where calibration data was often acquired) versus within buildings (where users often perform geolocation), further improving geolocation technology.

In ruling that all asserted claims were invalid under 35 U.S.C. § 101, the district court overgeneralized the claimed inventions to merely "determining an unknown location by comparing information about known locations organized in a database against measurements from a mobile device." This ignored the specific challenges addressed by the patents and the specific solutions recited in the claims. The district court failed to address its own claim construction—which contradicts its

characterization of the claim scope—and failed to credit the specifications or the pleaded averments concerning the nature and benefits of the inventions. Its conclusion was wrong *a priori*—the patents claim specific technological solutions to particular technological challenges in one form of geolocation, and therefore cover proper subject matter. But the district court compounded its error by asking the wrong question in the wrong framework and without considering the requisite record, as discussed below.

## STATEMENT OF THE ISSUES

1. Did the district court err in determining that the claims of U.S. Patent No. 8,406,753 are patent-ineligible where they claim improvements to the technological process of geolocation, including by generating and using novel data structures termed "grid points" to overcome technological challenges with signal propagation and improve the accuracy and efficiency of geolocation using network signals?
2. Did the district court err in determining that claim 2 of U.S. Patent No. 7,561,104, claim 18 of U.S. Patent No. 8,400,358, and claims 4 and 26 of U.S. Patent No. 8,786,494 are patent-ineligible where they claim improvements to the technological process of geolocation, including by generating and using novel data structures termed "non-uniform grid points" as well as novel approaches to generating calibration data and

comparing it to mobile device measurements to improve the accuracy and efficiency of geolocation using network signals?

## STATEMENT OF THE CASE

### A. Procedural History

Plaintiff-Appellant Geoscope filed its Complaint in the Google Action on November 22, 2022 and in the Apple Action on December 1, 2022. In both actions, Geoscope asserted infringement of U.S. Patent Nos. 7,561,104 ("'104 Patent"), 8,400,358 ("'358 Patent"), 8,786,494 ("'494 Patent")[1], 8,406,753 ("'753 Patent), 9,097,784 ("'784 Patent"), and 8,320,264 ("'264 Patent") (collectively, "Asserted Patents"). Appx257, Appx352. Although the actions were not consolidated, both cases were assigned to Judge Nachmanoff and their schedules were coordinated for discovery and most pretrial proceedings.

Geoscope and Defendant-Appellees Google LLC ("Google") and Apple Inc. ("Apple"; collectively, with Google, "Defendants") filed opening claim construction briefs on May 26, 2023 and responsive briefs on June 9, 2023. Defendants' briefs were substantially identical. The district court held a claim construction hearing on July 6, 2023. On July 19, 2023, the district court issued its claim construction

[1] The '104, '358, and '494 Patents have substantially identical specifications and are referred to collectively as the "'104 Patent Family." For simplicity, citations for the '104 Patent Family are only to the '104 Patent although the '358 and '494 Patents include the same language.

opinion—applicable to both actions—construing ten disputed terms across the Asserted Patents and adopting six stipulated constructions. Appx2733, Appx2767. Following claim construction, Geoscope stipulated to partial judgment of invalidity of the ’784 Patent and non-infringement of the ’264 Patent in both actions. Appx2937, Appx2942.

On June 27, 2023, Defendants filed substantially identical motions for judgment on the pleadings, contending that the Asserted Patents are not patent-eligible under 35 U.S.C. § 101. The briefing was completed on July 20, 2023 and the district court held a hearing on August 11, 2023. On September 18, 2023, the district court issued its opinions and orders granting Defendants’ motion for judgment on the pleadings.[2] Appx1, Appx24, Appx47, Appx48. Because of the parties’ prior stipulation as to the ’784 and ’264 Patents, the district court did not address them. The district court entered final judgment on October 5, 2023 in the Apple Action and on October 6, 2023 in the Google Action. Appx49, Appx50. Geoscope timely filed its notice of appeal in both actions on September 25, 2023. Appx2954, Appx2956.

This appeal is only directed to the district court’s ruling on the patent eligibility of certain claims of the ’104 Patent Family and the ’753 Patent (“Appealed

[2] The opinions and orders are substantively identical between the two actions, with minor differences—*e.g.*, for referencing the applicable party.

Patents"). The claims on appeal are independent claims 1 and 32 of the '753 Patent, dependent claim 2 of the '104 Patent, dependent claim 18 of the '358 Patent, and dependent claims 4 and 26 of the '494 Patent. Each appealed claim of the '753 Patent requires "grid points" and each appealed claim of the '104 Patent Family requires "non-uniform grid points."

### B. Factual Background

#### 1. Andrew Corporation and CommScope

Andrew Corporation was founded in 1937 to manufacture equipment for wireless communications systems, including directional antennas used in radio broadcasts. Over the years, Andrew Corporation became a leading global supplier and developer of wireless network equipment, hardware, and infrastructure. Appx263 ¶ 31.[3] By the early 2000s, Andrew Corporation began developing and manufacturing technology for the geolocation of mobile devices such as cellphones.

[3] The Federal Circuit consolidated the appeals from the Google Action and the Apple Action as Case Nos. 24-01003 (Lead), 24-1018 (member), ECF Nos. 11-12. Therefore, the joint appendix includes materials from the Google and Apple Actions, many of which are substantially identical. For example, the district court issued separate patent eligibility and claim construction opinions in the Google and Apple Actions though they are substantially identical in both actions. *Compare* Appx1-23 *with* Appx24-46; *compare* Appx2733-2766 *with* Appx2767-2800. Additionally, the complaints in the Google and Apple Actions are identical with respect to certain background information regarding the Asserted Patents and the field of geolocation. Thus, to avoid duplicative cites, Geoscope's joint appendix cites are to the materials from the Google Action unless necessary to distinguish them from the same materials from the Apple Action.

In that timeframe, Andrew Corporation touted itself as "the world's most experienced supplier of high-accuracy mobile location systems," stating that its Geometrix® mobile location systems "have been installed by more operators than any competing system" and "provide accurate location of mobile users who call police, fire, and medical emergency services from wireless devices." ANDREW CORPORATION ACQUIRES WIRELESS LOCATION BUSINESS ASSETS FROM NORTEL, https://www.commscope.com/press-releases/2005/andrew-corporation-acquires-wireless-location-business-assets-from-nortel/ (last visited Nov. 16, 2023). Throughout the early-mid 2000s, Andrew Corporation expanded its geolocation technology offerings, which were sought out by customers via contracts worth tens of millions of dollars. *See*, *e.g.*, ANDREW AWARDED SECOND PHASE OF STRATEGIC INTERNATIONAL GEOLOCATION CONTRACT, https://www.commscope.com/press-releases/2006/andrew-awarded-second-phase-of-strategic-international-geolocation-contract/ (last visited Nov. 16, 2023). The inventions underlying the Appealed Patents were conceived and reduced to practice during this time, and the provisional application to which they all claim priority was filed on February 5, 2007.

On June 27, 2007, CommScope, Inc., a network infrastructure provider, announced its acquisition of Andrew Corporation for approximately $2.6 billion. Appx263 ¶ 32. As explained in the press release announcing the acquisition, "[t]he

combined company will be a global leader in infrastructure solutions for communications networks, including structured cabling solutions for the business enterprise; broadband cable and apparatus for cable television applications; and antenna and cable products, base station subsystems, coverage and capacity systems, and network solutions for wireless applications." *Id*. CommScope subsequently assigned the Appealed Patents to Geoscope.

### 2. Geolocation of Mobile Devices

Geolocation refers to the process of determining the geographic location of a user or device. Geolocation has long been an important technological field, with extensive research and development dedicated to it by universities and industry, because it has many valuable uses. Geolocation is necessary to enable location-based services—*i.e.*, services that provide information to a user, or perform another function for a user, based on the user's location. Appx264 ¶ 36. Location-based services include, for example, "roadside assistance, turn-by-turn driving directions, concierge services, location-specific billing rates and location-specific advertising." Appx185 at 1:37-45.

Location-based services are particularly important for mobile devices because of their portability. Appx264 ¶ 37. By the priority date of the Appealed Patents in early 2007, the use of mobile devices such as "telephones, pagers, personal digital assistants, [and] laptop computers" had become prevalent, necessitating

improvements in their geolocation capabilities. Appx185 at 1:24-28. As such devices have become more advanced and ubiquitous, the importance of geolocation has only grown. For example, smartphones have allowed for a wider variety of location-based services such as rideshare and social networking applications, which have become commonly used location-based services. To be useful, these services require geolocation to be both accurate and efficient (*e.g.*, with respect to the time it takes for geolocation or the battery consumption required for it). A smartphone that determines its location inaccurately, takes several minutes to determine its location, or uses significant battery power to determine its location greatly diminishes the value of these location-based services. Thus, as described below, obstacles to providing accurate and efficient geolocation have to be overcome so users can take full advantage of location-based services.

Geolocation is often colloquially equated with GPS ("Global Positioning System"), a system designed for geolocation. Geolocation via GPS relies on signals transmitted by satellites orbiting the earth, a significant infrastructure created specifically for geolocation purposes. Mobile devices receive signals from GPS satellites and perform travel time and triangulation calculations with them to determine their locations.

But GPS has drawbacks. It requires an enormous commitment of resources, both in terms of satellite hardware and maintenance, and dedicated spectrum used

only for geolocation. Moreover, because GPS signals are transmitted by satellites in space, they are subject to interference as they travel through the atmosphere. Appx265 ¶ 40. The signals can also be obstructed by buildings, signs, trees, and the like. *Id*. Multipath interference, which occurs when GPS signals reflect off environmental objects, can cause further issues. These factors can reduce the accuracy of GPS-based geolocation—particularly indoors and in dense urban environments—and may even prevent GPS-based geolocation if a mobile device is not able to receive signals from a minimum number of GPS satellites needed to determine its location. *Id*.

Furthermore, it may take several minutes for a mobile device to receive the signals it needs from GPS satellites, sometimes referred to as a "time to first fix." *Id*. Additionally, GPS-based geolocation can be battery-intensive, particularly in environments where GPS signals are weak (*e.g.*, indoors). Thus, using GPS signals alone is often insufficient to achieve quick, accurate, and efficient geolocation of mobile devices. *Id*.

As a way of mitigating these drawbacks, geolocation of mobile devices often involves more than, or alternatives to, GPS. One technology that can be employed is geolocation using network signals—*e.g.*, cellular signals. Appx266 ¶ 41. These network signals are propagated by transmitters such as cell towers to enable networks. *Id*. Mobile devices receive these signals as part of identifying and

connecting to such networks but these signals can also be repurposed for geolocation. *Id*. Thus, in the field of geolocation, they are sometimes referred to as "signals of opportunity"—although they exist for a different purpose, they can be opportunistically repurposed for geolocation.

Using network signals for geolocation mitigates many drawbacks of GPS. Unlike GPS signals, network signals do not have to pass through the earth's atmosphere and are not subject to interference from doing so. Additionally, using network signals for geolocation can avoid potentially long times to first fix for GPS-based geolocation. Moreover, using network signals for geolocation—in place of GPS or to supplement GPS—can often decrease the battery consumption associated with geolocation.

### 3. The Inventions of the Appealed Patents

Although using network signals for geolocation has many benefits and can mitigate the drawbacks of GPS, it presents its own challenges that can compromise the accuracy and efficiency of geolocation. The Appealed Patents are directed to inventions that overcome challenges specific to geolocation using network signals, and thus improve the process of geolocation itself.

Prior art approaches to using network signals for geolocation typically used triangulation or trilateration. With these approaches, mobile devices receive network signals and measure parameters of them such as the "time of arrival" or "angle of

arrival." *See* Appx185 at 1:49-61. Complex geometric calculations can then be performed with these parameters to try to determine where the mobile device is located. For example, the angles of arrival for multiple signals received by a mobile device can be used to calculate triangular relations between the sources of the signals (*i.e.*, transmitters at known locations) and the recipient of the signals (*i.e.*, the mobile device), resulting in an estimated location for the mobile device—hence the term "triangulation."

But geolocation using network signals is heavily dependent on the availability of such signals and accurate measurements of them. When there is limited signal information available, or the signals are attenuated, the quality of geolocation suffers. Therefore, although using network signals can be beneficial, it creates its own set of challenges associated with providing quick, accurate, and efficient geolocation. Appx267-68 ¶ 44.

These challenges were recognized as of the 2007 priority date of the Appealed Patents. As one example, geolocation using network signals typically requires a sufficient number of transmitters within an area to provide enough signal information corresponding to known locations for the geolocation to be accurate. Appx268 ¶ 45. In areas where there is only a sparse "map" of known locations with associated signal information, the geolocation will not be as accurate or efficient, and may not even be possible. *Id*.

Conventional geolocation systems could attempt to mitigate this issue by performing more complex calculations using the limited information available, but this required sophisticated hardware and significant processing power. Appx274-75 ¶ 59. Regardless, the further a mobile device is from a known reference location, the greater the uncertainty and error of the geolocation. *Id*.

The Appealed Patents employ a different approach to using network signals for geolocation that involves a calibration and "grid point" generation process. *First*, calibration data is collected or determined using measurements of network signals. Appx267 ¶ 43. As an example of a calibration process, mobile devices receive cellular signals (from different cell towers) at a number of locations that are known (*e.g.*, based on GPS) and measure the strengths, or other properties, of those signals. *Id*. These measurements—which constitute calibration data—include information about the properties of the signals transmitted by those cell towers, as received at those particular known locations.

The appealed claims of the '753 Patent and the '104 Patent Family are directed to improvements in geolocation technology through the generation and use of what the patents refer to as "grid points." As used in the Appealed Patents, "grid points" are not merely points on a grid. Rather, as explained below, the grid points of the Appealed Patents are data structures that are generated and associated with signal information based on analysis of the similarities between calibration data (*e.g.*,

measurements of network signals propagating in a region) that has been previously collected. That calibration data is collected via "Network Measurement Reports" (or "NMRs"), a type of report containing information about cellular signals.

Because the grid points are generated dynamically based on the calibration data as it is measured—rather than being predefined—their location, boundaries, and associated signal information are not defined until determined from particular aspects of the calibration data. The grid points serve as additional known locations associated with network signal information, creating a denser "map" for mobile devices to compare observed data to for the purpose of determining their location. Thus, the inventions of the appealed claims solve a particular technological problem, and there by improve the process of geolocation itself.

Because the "signals of opportunity" used in the claimed approach will not travel regularly or uniformly—or even predictably—through real world environments, the resulting grid points of the Appealed Patents based on actual measured data "usually will not be uniformly distributed throughout the geographic region," and thus the Appealed Patents often interchangeably use the term "non-uniform grid points" or "NUGs" when describing them. *See* Appx185 at 2:43-50; *see also* Appx63 at 3:50-60. Additionally, the claimed grid points "represent an area of collected calibration data," not just a predefined grid laid over a geographic region. Appx63 at 3:56-60. Accordingly, the district court construed "grid point"

contrary to its plain and ordinary meaning as "a point associated with representative calibration data for an area." Appx2785-86.

In its *Markman* order, the district court provided further detail about the meaning of "grid point" in the Appealed Patents and its construction of the term. *First*, the district court stated that the '753 Patent's explanation that calibration data from a number of locations is "gathered and analyzed so that particular grid points within the geographic region can be determined and associated with a particular set or sets of calibration data" demonstrates "what *must be done* to arrive at a grid point or set of grid points." Appx2751 (quoting '753 Patent at Abstract) (emphasis in original). Thus, the district court acknowledged that the claimed grid points must be generated based on the measured calibration data—they do not exist until generated by the claimed invention. *Second*, the district court explained that "representative calibration data" in its adopted construction reflects that "the defining characteristic of a NUG region … is that the data points within an area are all 'statistically very similar' such that each of the grid points within the NUG region can represent the overall NUG." Appx2752 (citing '104 Patent at 3:56-60; '753 Patent at 10:29-11:7; '784 Patent at 6:22-28). In other words, the geographic boundaries of the claimed grid points are undefined until determined by the claimed invention based on similarities across the measured calibration data.

Thus, although termed "grid *points*," they are not just "points"—they represent a broader area whose boundaries are defined by the commonality of the calibration data measured in the region. And although the term "*grid*" is used, these irregular and dynamic structures are nothing like the conventional understanding of grids as "a network of uniformly spaced horizontal and perpendicular lines." *See, e.g.*, GRID DEFINITION & MEANING, https://www.merriam-webster.com/dictionary/grid (last accessed Nov. 16, 2023). This can be seen in the figure below from the related '784 Patent[4] which depicts exemplary grid points of the Appealed Patents, showing "a geographical region (R) having NUGs represented by NUG1, NUG2, and NUG3," and explaining "[a] NUG may be generated to represent the signal characteristics and calibration data over a given region." Appx227 at Fig. 6, Appx233 at 6:21-34.

[4] The '784 Patent, which claims priority to the same provisional application as the Appealed Patents, also describes "grid points" as the term is used in this patent family. Consequently, the district court relied on disclosures in the '784 Patent in construing the term "grid point." Appx2752 (citing '784 Patent (as "Ex. F") at 6:22-28).

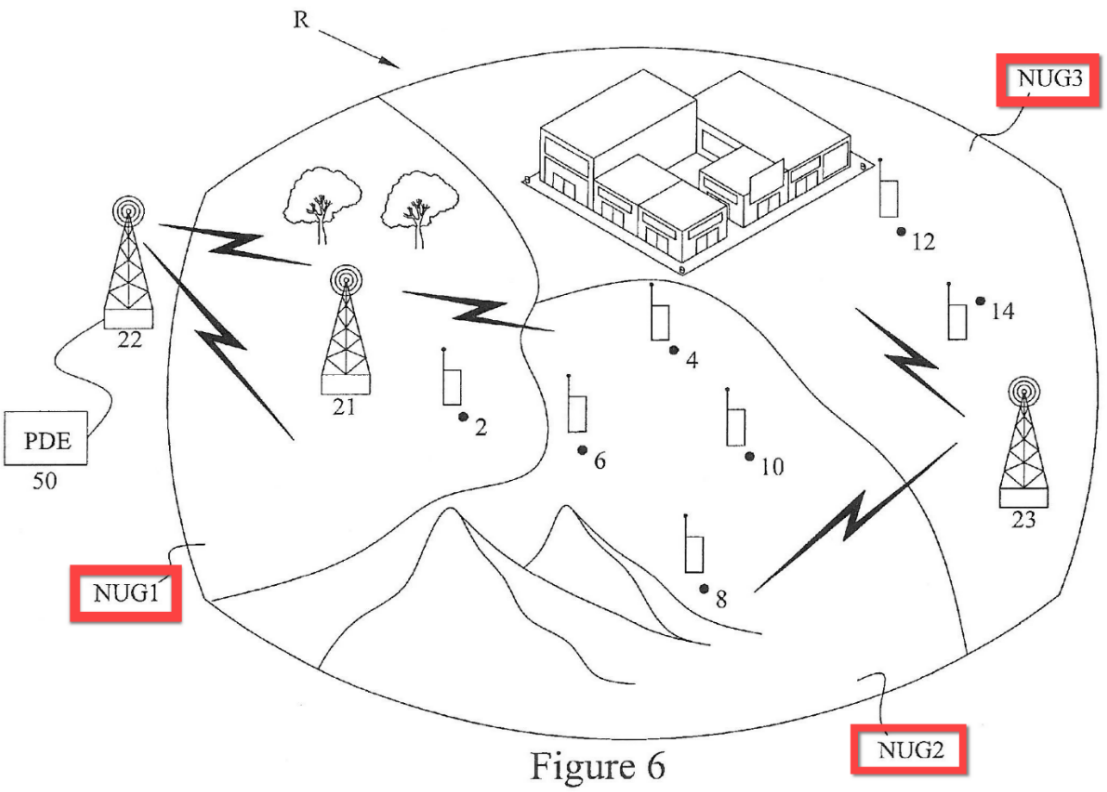



Figure 6

(three grid points NUG1-3, generated from calibration data measured at points 2-14, and used to fill in the "map" between cell towers 21-23)

To generate grid points, calibration data for a number of locations is "gathered and analyzed so that particular grid points within the geographic region can be determined and associated with a particular set or sets of calibration data." Appx111 at Abstract, Appx189 at 9:34-39. The calibration data used to generate grid points "may be obtained at each of several calibration points, which may be discrete points within region R each having geographical coordinates (e.g., latitude and longitude) associated therewith" and can include information regarding, for example, signal strength. *Id*. at 9:56-10:7. This calibration data is collected via "Network Measurement Reports" (*see id*. at 9:53-56), which are "report[s] used in cellular

networks which provide[] the results of a measurement from a mobile device on one or more cells." Appx2749-50. A single point—the "grid point" or "non-uniform grid point"—is then generated and includes specific coordinates but is also defined by the geographic area comprising similar calibration data. *See* Appx189 at 9:34-48. For this reason, the set of grid points may be well-defined and ordered from a measured network signal perspective, but appears irregular and non-uniform from a geographic perspective, as shown in the figure above.

Generating the claimed grid points includes determining their location (or "geographical coordinates") and boundaries based on evaluation of the calibration data. *Id*. at 9:34-40, Appx190 at 12:9-14; *see also* Appx185 at 2:51-60. Because the claimed grid points are generated from calibration data gathered in a region, they are tailored in location and shape to that region based on the available calibration data. Appx190 at 12:9-14. Additionally, generating grid points includes associating them with "characteristics" that describe the grid point—*e.g.*, information about signal strengths derived from the measured calibration data. *Id.* at 12:26-50. Thus, as taught in the specification, each grid point is a data structure that captures the necessary components to define parameters of the network signals in a region and their propagation:

> For each so obtained NUG [non-uniform grid point], a variety of parameters and functions may be generated and stored to describe that NUG. These are termed the NUG characteristics. The NUG characteristics are a representation in that attempt to capture the nature

> and variability of the data associated with that NUG in a compact and representative form. These characteristics may include, but are not limited to, the following: (a) an ordered list of neighboring cells; (b) functions defined on the absolute neighboring cell power levels (e.g., mean, median, kth moment, cluster-mean, etc.); (c) functions defined on the relative neighboring cell power differences (e.g., mean, median, kth moment, cluster-mean, etc.); (d) serving cell/sector; (e) timing advance parameter (or equivalent); (f) individual pdf (probability density function or probability distribution function) of each neighboring cell power level; (g) joint pdf of neighboring cell power levels; (h) mean and variance of neighboring cell power levels; (i) mobile device orientation (e.g., indoors, outdoors, direction mobile device is facing (e.g., North, South, etc.), tilted upwards, azimuth, elevation, etc.); (j) a compact and/or efficient representation that enables retrieval of the calibration data NMR vectors assigned to this NUG; (k) the network state as indicated in the calibration data; (l) a confidence measure indicative of the reliability of the calibration data feeding this NUG …

*Id*. The claimed grid points are new creations that define a geographic area based on the measured propagation of signals of opportunity in the area, and capture parameters of that propagation to enable later geolocation using observed signals.

The Appealed Patents describe how grid points are generated based on analyzing calibration data to assess the commonality of such data using, for example, "increasingly stringent tests of statistical sufficiency":

> The root of the NUG may be the calibration data vector that initiates the creation of that NUG. The vectors may be examined using, for example, increasingly stringent tests of statistical sufficiency. In particular, a determination may be made as to whether the data vectors exhibit clustering. If the data exhibits tight clustering, the data for the next candidate calibration point may be aggregated to the former calibration point and the clustering property may be re-evaluated. For example, if the second calibration point also has a cluster but this cluster is sufficiently different than the cluster of the first calibration point, a

> determination may be made that the data for the two considered calibration points should be allocated to the roots of separate NUGs. If the aggregate cluster (i.e., a cluster including data from both the first and second calibration points) is statistically very similar to either of the first or second clusters (taken independently), then the data for the two calibration points may be allocated to the same NUG. All adjacent calibration data points may be similarly evaluated with respect to the first considered calibration point.

Appx189 at 10:43-61. Thus, the statistical similarity of the calibration data can be evaluated to determine where a grid point should be generated, if one should be generated at all. Appx189-90 at 10:66-11:6. The statistical similarity in the calibration data can be assessed based on clustering tests, a probability density function, the mean and variance of the data, or other functions of the calibration data. *Id.* at 10:66-11:6, 12:4-14.

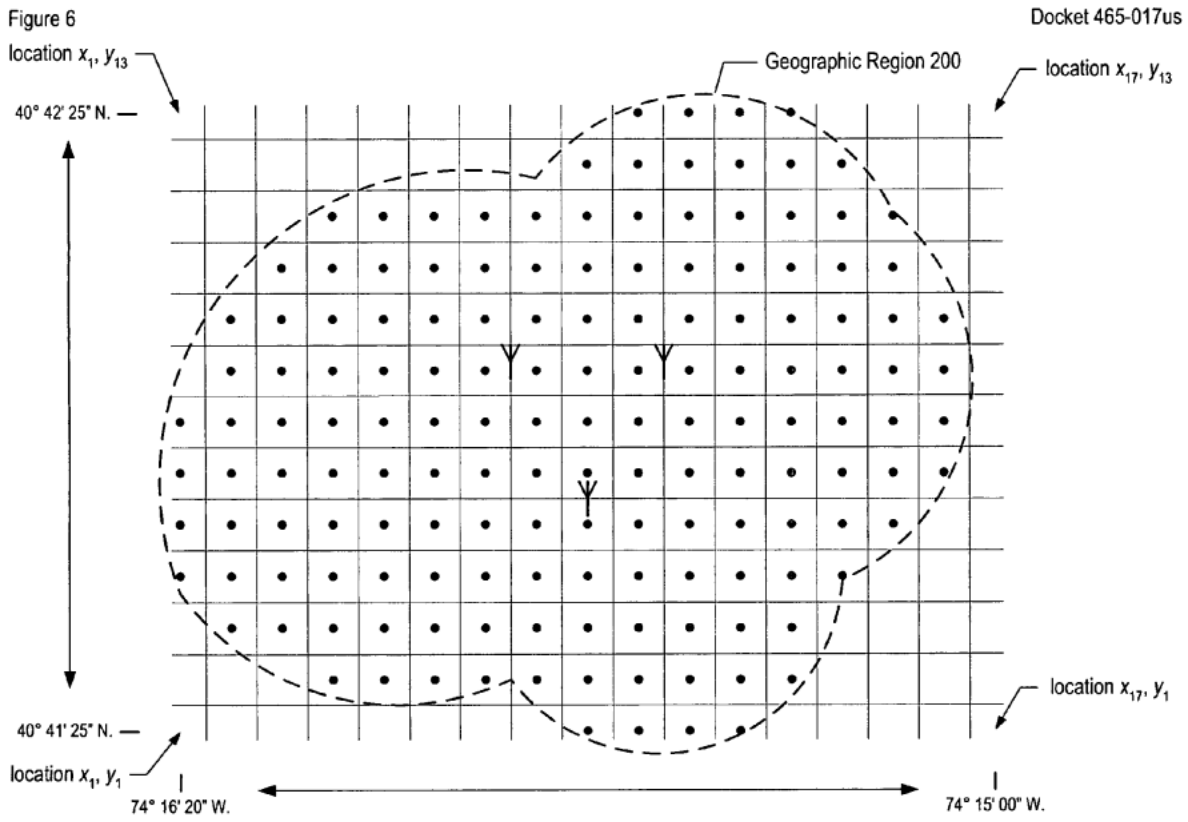
Because of the specific manner in which the claimed grid points are generated, the "grid" of the Appealed Patents does not exist—and is not defined—until the calibration data is gathered and analyzed to generate the claimed "grid points," each with a unique shape and geographic area dictated by the propagation of the network signals in a region, as determined from the measured calibration data. Thus, even network signal-based geolocation systems using grids are markedly different from the inventions of the Appealed Patents because such systems merely used conventional grids and points. For example, U.S. Patent No. 5,327,144 ("'144 Patent"; Appx2315)—which is cited on the face of the '358 Patent (*see* Appx71),

and thus part of the intrinsic record[5]—was relied on below by Defendants as purportedly demonstrating that it was well-known and conventional to use grids for geolocation. However, the ’144 Patent is directed to “estimating the location of a cellular telephone” involving “creating a grid of theoretical points covering a prescribed geographic area, ***the theoretical points being spaced at prescribed increments of latitude and longitude***.” Appx2333 at 6:56-61 (emphasis added). In other words, the “grid of theoretical points” in the ’144 Patent is not determined based on the calibration data—as the grid points of the Appealed Patents are—but rather is defined in advance independently of any calibration data.

This distinction between conventional grids and the claimed grid points of the Appealed Patents is even more apparent from other intrinsic evidence such as U.S. Patent No. 7,796,966 (“’966 Patent”, *available at* https://image-ppubs.uspto.gov/dirsearch-public/print/downloadPdf/7796966 (last accessed Nov. 16, 2023)), which is cited on the face of the ’753 Patent (*see* Appx112). The ’966 Patent describes a “process and machine for estimating the location of a wireless terminal.” ’966 Patent at Abstract. The process uses a “rectangular grid of X by Y tessellated squares [that] is overlaid onto” a geographic region. *Id*. at 10:21-23 (referencing Figure 6). This grid is depicted below—as is readily apparent, it is

[5] Prior art “cited in a patent or cited in the prosecution history of the patent constitutes intrinsic evidence.” *V-Formation, Inc. v. Benetton Grp. SpA*, 401 F.3d 1307, 1311 (Fed. Cir. 2005).

merely a conventional grid that looks significantly different from that of the Appealed Patents, shown above.




(conventional grid—a "network of uniformly spaced horizontal and perpendicular lines"—used to partition a region for prior art geolocation methods)

*Id*. at Fig. 6. This conventional grid of the '966 Patent and its constituent points are not generated from calibration data as they are part of a preexisting "overla[y]" onto a geographic region. *Id*. at 10:21-23, 10:53-60. Thus, the grid points of the Appealed Patents are fundamentally different from conventional grids and points thereon.

Once the claimed grid points are generated, they can be used in connection with geolocating a mobile device. "The location of a wireless device may be

estimated by comparing data reported by the mobile device to be geolocated with the data (and more particularly the characteristics derived from this data) associated with the various grid points to thereby estimate the location of the mobile." Appx189 at 9:43-48. This involves evaluating data observed by the mobile device and selecting the set of generated grid points that are appropriate for comparison to that observed data based on predetermined criteria such as "total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance." Appx187 at 5:63-6:7, Appx210 at 51:27-33. As described in the Appealed Patents, this can include assigning the coordinates of a given grid point as the location of a mobile device, or interpolating between grid points for increased precision. *See*, *e.g.*, Appx193 at 18:57-60. For example:

> An exemplary weight assigned to the $i^{th}$ grid point in computing the final interpolated location may be determined by the following relationship:
>
> $$Wi = \frac{\frac{1}{Ci}}{\sum_{i=1}^{N}\left(\frac{1}{Ci}\right)}$$
>
> where $C_i$ is a metric associated with an $i^{th}$ grid point. Weighted averaging may also be utilized rather than uniform weighting to ensure that the best matching grid point (i.e., minimum cost grid point) exerts a larger influence on the final location estimate.

Appx196 at 23:63-24:13. The inventive geolocation is now based on the grid points closest to the mobile device, rather than relying on the sparse and distant distribution of cell towers.

The inventions of the appealed claims improved on conventional methods for geolocation using network signals through the generation and use of such grid points—as that term is used in the Appealed Patents—including non-uniform grid points. The inventions enabled using existing calibration data to create additional known locations, tailored to a region based on similarities across the calibration data, that are associated with network signal information. Appx275-77 ¶¶ 60-63. Thus, these grid points create a more robust "map" of such known locations which might otherwise be few and far between. *Id*. Instead of using signal information only from certain sources—*e.g.*, cell towers that may be far away from each other and the device—a mobile device could geolocate itself via comparison to newly-generated grid points, ensuring more accurate geolocation with simpler calculations. *Id*.

## SUMMARY OF THE ARGUMENT

The Appealed Patents claim specific improvements to the technological process of geolocation. Using a novel grid point data structure—"a point associated with representative calibration for an area"—the inventions created a denser reference map that improved the accuracy and efficiency of geolocation itself. As detailed in the specification and confirmed by the pleadings, this was an

unconventional approach, unlike any traditional conception of "grid points," that provided concrete technological benefits. The Appealed Patents do not merely claim the *use* of geolocation—they recite a concrete improvement *to geolocation itself*.

This is patentable subject matter. The Supreme Court and Federal Circuit have routinely found that improvements to technological processes are patent-eligible, particularly where those improvements involve novel, unconventional data structures. The Federal Circuit should reach the same conclusion here because the appealed claims provide a specific solution to a particular challenge in the field of geolocation.

The district court's contrary conclusion was based on an over-abstraction of the claims that failed to apply—or even acknowledge—its prior claim construction of "grid point" or any other claim limitation. Moreover, contrary to Federal Circuit law, the district court disregarded the patent specifications and Geoscope's well-pleaded allegations. These errors warrant reversal.

## ARGUMENT

### I. STANDARD OF REVIEW

Review of the grant or denial of motions that are not patent-specific—including a Rule 12(c) dismissal for judgment on the pleadings—is under regional circuit law. *MyMail, Ltd. v. ooVoo, LLC*, 934 F.3d 1373, 1378 (Fed. Cir. 2019). The Fourth Circuit reviews the grant of 12(c) motions *de novo*. *Conner v. Cleveland*

*Cnty., N.C.*, 22 F.4th 412, 419-20 (4th Cir. 2022). Judgment on the pleadings is only properly granted if, accepting as true the facts presented and drawing all reasonable inferences in favor of the non-moving party, "it appears certain that the plaintiff cannot prove any set of facts in support of [its] claim entitling [it] to relief." *Pulte Home Corp. v. Montgomery Cnty.*, 909 F.3d 685, 691 (4th Cir. 2018) (internal quotation marks and citation omitted).

Review of a district court's determination of patent-eligibility is *de novo*. *MyMail*, 934 F.3d at 1379. Patent eligibility under § 101 is a question of law that may contain underlying issues of fact. *Aatrix Software, Inc. v. Green Shades Software, Inc.*, 882 F.3d 1121, 1128 (Fed. Cir. 2018). "[P]atent eligibility can be determined on the pleadings under Rule 12(c) when there are no factual allegations that, when taken as true, prevent resolving the eligibility question as a matter of law." *CosmoKey Sols. GmbH & Co. KG v. Duo Sec. LLC*, 15 F.4th 1091, 1095-96 (Fed. Cir. 2021); *Coop. Ent., Inc. v. Kollective Tech., Inc.*, 50 F.4th 127, 130 (Fed. Cir. 2022) ("[P]atent eligibility may be resolved at the Rule 12 stage only if there are no plausible factual disputes after drawing all reasonable inferences from the intrinsic and Rule 12 record in favor of the non-movant."). "[P]lausible factual allegations may preclude dismissing a case under § 101 where, for example, 'nothing on th[e] record … refutes those allegations.'" *Aatrix*, 882 F.3d at 1125.

## II. APPLICABLE LAW

Section 101 provides that "[w]hoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor." 35 U.S.C. § 101. The Supreme Court established a two-step framework in *Alice* to assess patent eligibility under § 101. *Alice Corp. Pty. Ltd. v. CLS Bank Int'l*, 573 U.S. 208, 217-18 (2014). Under *Alice* Step One, the court determines "whether the claims at issue are directed to a patent-ineligible concept," such as an "abstract idea." *Id*. at 218. If not, then the claims are patent-eligible under § 101, and the analysis ends there. *Id*. at 217.

Because "all inventions at some level embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas," claims are not patent-ineligible merely because they involve or relate to some abstract concept. *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1335 (Fed. Cir. 2016) ("The 'directed to' inquiry, therefore, cannot simply ask whether the claims *involve* a patent-ineligible concept, because essentially every routinely patent-eligible claim involving physical products and actions *involves* a law of nature and/or natural phenomenon." (emphasis in original)). Accordingly, courts must avoid "describing the claims at such a high level of abstraction" that "the exceptions to § 101 swallow the rule." *Id*. at 1337. The overgeneralization of claims, "if carried to its extreme, make[s] all inventions unpatentable because all inventions can be reduced to underlying

principles of nature which, once known, make their implementation obvious." *Diamond v. Diehr*, 450 U.S. 175, 189 n.12 (1981).

To avoid oversimplifying the claims, courts must assess whether the claims "as a whole" are "directed to excluded subject matter." *Enfish*, 822 F.3d at 1335. This requires consideration of the claims "in light of the specification." *Id.*; *CardioNet, LLC v. InfoBionic, Inc.*, 955 F.3d 1358, 1368 (Fed. Cir. 2020) ("We also consider the patent's written description, as it informs our understanding of the claims."); *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295, 1303 (Fed. Cir. 2019) ("The specification bolsters our conclusion that the claims are directed to a technological solution to a technological problem.").

Claims that are directed to improvements in technological processes satisfy *Alice* Step One, and are patent-eligible. *Adasa Inc. v. Avery Dennison Corp.*, 55 F.4th 900, 908 (Fed. Cir. 2022) ("If the focus of the claim is a specific and concrete technological advance, for example an improvement to a technological process or in the underlying operation of a machine, our inquiry ends and the claim is eligible."); *Diehr*, 450 U.S. at 187-88 (holding claims reciting an improvement in the rubber curing process patent-eligible); *Thales Visionix Inc. v. United States*, 850 F.3d 1343, 1348-49 (Fed. Cir. 2017) (holding claims reciting improvement to determining the position of an object patent-eligible).

This is just as true for claims directed to improvements in computer-related technology. *Visual Memory LLC v. NVIDIA Corp.*, 867 F.3d 1253, 1258 (Fed. Cir. 2017) ("[I]t was appropriate to consider the technological improvement embodied in the claims at step one, we explained, because *Alice* does not 'broadly hold that all improvements in computer-related technology are inherently abstract and, therefore, must be considered at step two.'"); *Uniloc USA, Inc. v. LG Elecs. USA, Inc.*, 957 F.3d 1303, 1306 (Fed. Cir. 2020) ("In cases involving software innovations, this inquiry often turns on whether the claims focus on specific asserted improvements in computer capabilities or instead on a process or system that qualifies an abstract idea for which computers are invoked merely as a tool.").

Claims that do not satisfy *Alice* Step One are still patent-eligible under *Alice* Step Two if they include an "inventive concept," such as "an element or combination of elements that is sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the ineligible concept itself." *Alice*, 573 U.S. at 217-18. "The 'inventive concept' may arise in one or more of the individual claim limitations or in the ordered combination of the limitations." *Bascom Glob. Internet Servs., Inc. v. AT&T Mobility LLC,* 827 F.3d 1341, 1349 (Fed. Cir. 2016). The "inventive concept" can be found in "the non-conventional and non-generic arrangement of known, conventional pieces." *Id.* at 1350. Therefore, the "inquiry

requires more than recognizing that each claim element, by itself, was known in the art." *Id.*

## III. THE CLAIMS OF THE '753 PATENT ARE PATENT-ELIGIBLE

The district court found that independent claims 1 and 32 of the '753 Patent are patent-ineligible. Claim 1 of the '753 Patent recites:

> 1. A method of determining the location of a mobile device in a geographic region comprising the steps of:
>
> (a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;
>
> (b) generating one or more sets of grid points for said calibration data;
>
> (c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;
>
> (d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;
>
> (e) selecting a set of grid points as a function of predetermined criteria; and
>
> (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points.

Appx214 at 59:14-31. Claim 32 of the '753 Patent is a system claim corresponding to claim 1, and thus is highly similar to claim 1. Appx216 at 63:49-67.

### A. Step One: The Claims of the ’753 Patent Recite a Specific Improvement to Geolocation Technology that is Not Abstract

The ’753 Patent claims are directed to a specific improvement to geolocation technology that solves a recognized problem in that field—the sparsity of reference points and the non-predictability of signal propagation between those points. The claimed improvement involves the generation of novel data structures referred to as “grid points.” This is patentable subject matter. The district court’s cursory *Alice* Step One analysis—which totals just over two pages (*see* Appx20-22)—is inconsistent with § 101 precedent from the Supreme Court and Federal Circuit.

Under *Alice* Step One, the district court found the claims to be directed to the abstract idea of “determining an unknown location by comparing information about known locations organized in a database against measurements from a mobile device.” Appx20. The district court stated that “[i]n essence, the asserted claims of the ’753 Patent merely purport to collect and organize data in a reference database and to compare the data received from an unknown location to data in the selected database of known locations.” *Id*. Additionally, the district court concluded that “the claims recite no specific solution to make the alleged improvement concrete” because “nothing in the claims requires the grid points to be (1) arranged in a ‘denser ‘map’ of known locations,’ (2) ‘determined from the analysis of calibration data,’ or (3) organized in any specific format.” Appx21-22 (internal citations omitted). The district court is incorrect as to all three, and in reaching these conclusions, the district

court committed error by oversimplifying the claims as a result of disregarding its own claim constructions and the ’753 Patent specification. Thus, the district court’s ruling should be reversed.

### 1. The district court improperly overgeneralized the ’753 Patent claims by ignoring its adopted claim constructions

The district court construed multiple terms in the ’753 Patent prior to issuing its § 101 opinion. *See* Appx2748-52. ***But nowhere in its Alice Step One analysis did the district court address—or even consider—its claim constructions***. *See generally* Appx20-22. The very purpose of claim construction is to “determin[e] the meaning and scope of the patent claims asserted.” *Markman v. Westview Instruments, Inc.*, 52 F.3d 967, 976 (Fed. Cir. 1995) (en banc). As explained below, by disregarding its own claim constructions, the district court overlooked important aspects of what is claimed that it had recognized itself just two months prior during claim construction. Without consideration of the claim language ***as construed***, the district court’s opinion was not based on a “full understanding of the basic character of the claimed subject matter,” as required. *MyMail*, 934 F.3d at 1379.

The Federal Circuit has recognized that a proper § 101 analysis can turn on issues of claim construction, confirming that the district court erred in disregarding its constructions. For example, in *Finjan, Inc. v. Blue Coat Sys., Inc.*, 879 F.3d 1299 (Fed. Cir. 2018), the Federal Circuit relied on the district court’s construction of “Downloadable security profile that identifies suspicious code in the received

Downloadable"—as well as what the "district court's claim construction decision emphasize[d]" about the requirements of the claim—in holding the claim was directed to a patent-eligible "improvement in computer functionality." *Id*. at 1303-04. Several other Federal Circuit decisions have similarly demonstrated that claim construction is central to a proper § 101 analysis.[6] *MyMail*, 934 F.3d at 1379-81 (vacating § 101 ruling because "the district court erred by failing to address the parties' claim construction dispute before concluding, on a Rule 12(c) motion, that the MyMail patents are directed to patent-ineligible subject matter under § 101"); *Sequoia Tech., LLC v. Dell, Inc.*, 66 F.4th 1317, 1325-26 (Fed. Cir. 2023) ("[W]e disagree with the district court's claim construction and, consequently, reverse the district court's holding that claims 8–10 are ineligible under § 101."); *Adasa*, 55 F.4th 900, 908-09 (relying on district court's claim construction in holding that claims were directed to patent-eligible subject matter).

[6] Although claim construction is not *per se* mandatory for a § 101 analysis where "claims are directed to ineligible (or eligible) subject matter under all plausible constructions" or where the non-movant fails to "provide an actual proposed construction, to demonstrate that its construction is not frivolous, and to articulate how adoption of the construction would materially impact the analysis at step one (and/or at step two)," that is not the case here. *See Sanderling Mgmt. Ltd. v. Snap Inc.*, 65 F.4th 698, 704 (Fed. Cir. 2023). The district court issued its claim construction opinion on July 19, 2023 while the § 101 issue was still being briefed. Appx2733. Thus, by the time the district court ruled on the § 101 issue on September 18, 2023, it had already construed the claims, and those constructions were addressed during the § 101 hearing. *See, e.g.,* Appx2899-901 at 33:13-35:18, Appx2924-26 at 58:6-60:14, Appx2929 at 63:8-22; *see also* Appx3245-46.

*Enfish* is particularly instructive in this regard. The Federal Circuit relied on the district court's construction of "means for configuring" as a particular "four-step algorithm" in finding the claims were "specifically directed to a *self-referential* table for a computer database." *Enfish*, 822 F.3d at 1336-37 (emphasis in original). The claims, as written, did not use the term "self-referential" but the construction of "means for configuring" did. *Id*. Thus, the Federal Circuit focused on the underlying construction in concluding the claims were directed to patentable subject matter under *Alice* Step One. The district court erred in not doing so here.

The district court construed multiple terms in the '753 Patent, recognizing they mean something specific. The district court construed "network measurement report" as "a report used in cellular networks which provides the results of a measurement from a mobile device on one or more cells," recognizing the specific manner in which calibration data and observed data is collected as part of the claimed invention. Appx2749-50. The district court also construed "calibration data" as "modified or unmodified network measurement data associated with a geographic location." Appx2738-2740. And as discussed above, the district court construed "grid point" as "a point associated with representative calibration data for an area." Appx2750-52. Yet, the district court did not consider ***any*** of these constructions in its § 101 analysis. *See* Appx20-23.

This is particularly egregious with respect to the term "grid point" because the district court had already acknowledged that the claimed grid points are not something generic—they are not merely any points on a grid or any reference point. ***Indeed, during claim construction, the district court recognized multiple specific aspects of the claimed grid points that it ignored in its § 101 analysis.*** Quoting the '753 Patent's explanation that calibration data is "gathered and analyzed so that particular grid points within the geographic region can be determined," the district court explained that this shows "what *must be done* to arrive at a grid point or set of grid points." Appx2751 (quoting '753 Patent at Abstract) (emphasis in original). Moreover, the district court explained that the use of "representative calibration data" in its construction "reflect[s] that ***the defining characteristic of a NUG region—as explained in the specifications of the '753 Patent, '104 Patent, and ['784] Patent***—is that the data points within an area are all 'statistically very similar' such that each of the grid points within the NUG region can represent the overall NUG." Appx2752 (citing '104 Patent at 3:56-60; '753 Patent at 10:28-11:7; '784 Patent at 6:22-28) (emphasis added).

Thus, during claim construction, the district court recognized that the claimed grid points are data structures (1) generated dynamically based on analysis of gathered calibration data and (2) associated with data that is representative of an area in a particular manner—*i.e.*, based on statistical similarity. *See* Appx2751-52. This

is how they are described in the specification: "The NUG characteristics are a representation in that attempt to capture the nature and variability of the data associated with that NUG in a compact and representative form," and can include a "list of neighboring cells," "functions defined on the absolute neighboring cell power levels," "probability density function[s] or probability distribution function[s]," "calibration data NMR vectors assigned to th[e] NUG," and "a confidence measure indicative of the reliability of the calibration data feeding th[e] NUG." Appx190 at 12:26-50.

Yet, the district court did not consider those aspects—either as recited in the specification or as explicitly captured by its claim construction—when assessing the '753 Patent claims under § 101. *See generally* Appx20-22. By disregarding those aspects in its § 101 analysis, the district court effectively construed the term one way for infringement and another for validity. This is contrary to blackletter law that "claims are construed the same way for both invalidity and infringement." *Amgen Inc. v. Hoechst Marion Roussel, Inc.*, 314 F.3d 1313, 1330 (Fed. Cir. 2003).

Notably, the aspects of the claimed grid points the district court recognized during claim construction contradict the district court's basis for finding the claims are directed to an abstract idea. The district court stated that "nothing in the claims requires the grid points to be … determined from the analysis of calibration data." Appx22. This is incorrect. The claims explicitly require "providing calibration data"

and then "generating one or more sets of grid points ***for said calibration data.***" Appx214 at 59:16-20 (emphasis added); *see also* Appx216 at 63:52-60. Moreover, the concept is required ***by the district court's own order*** that defined "grid points" as being "associated with representative calibration data for an area" and explained that gathering and analyzing calibration data is "what *must be done* to arrive at a grid point or set of grid points." Appx2751-52 (emphasis in original). Despite this, the district court ignored the broader requirements of the claims and the context of the specification, treating the limitation as "simply recit[ing] 'generating one or more grid points.'" Appx22.

In its two-page *Alice* Step One analysis, the district court entirely disregarded its claim constructions despite those constructions defining the meaning and scope of the '753 Patent claims. This led the district court to improperly oversimplify the patented invention in a manner that the Supreme Court and Federal Circuit have long warned against. *Alice*, 573 U.S. at 217 (explaining that courts must "tread carefully" in applying § 101 because "all inventions ... embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas."); *McRO, Inc. v. Bandai Namco Games Am. Inc.*, 837 F.3d 1299, 1313 (Fed. Cir. 2016) ("We have previously cautioned that courts 'must be careful to avoid oversimplifying the claims' by looking at them generally and failing to account for the specific requirements of the claims."). Thus, the district court's ruling should be reversed. As explained below,

under the proper § 101 analysis—with consideration of the construed claim language viewed in light of the specification—the '753 Patent claims are directed to patent-eligible improvements to the technological process of geolocation.

### 2. The '753 Patent claims are directed to a specific improvement to geolocation technology that uses novel data structures to solve a problem in the field

Consistent with the district court's claim construction, the '753 Patent and related patents confirm that the claimed grid points are not just points on a conventional grid. This is clear from the description of grid points in these patents as well as the depiction of them in the related '784 Patent: [7]

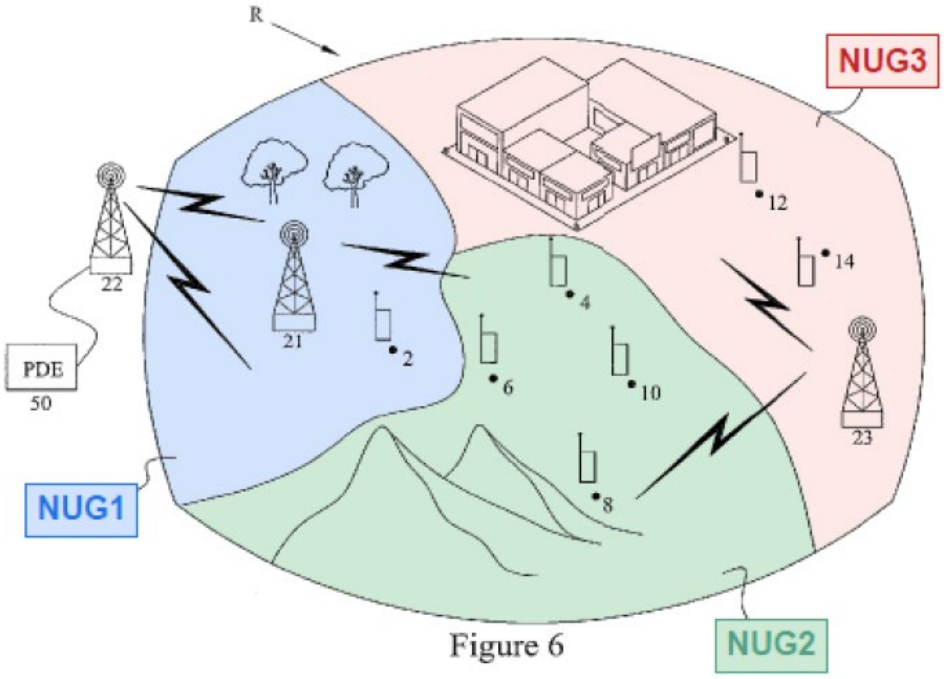


Figure 6

[7] As explained above, the '753 Patent and related patents often use the term "non-uniform grid points" or "NUGs" when describing grid points. *See supra* at 16.

Appx3221; *see also* Appx227 at Fig. 6.

The figure "illustrates a geographical region (R) having NUGs represented by NUG1, NUG2, and NUG3." Appx233 at 6:22-24. "The NUGs represent an area of collected calibration data based on data collected via data collection devices and/or signals transmitted from the mobile stations (MSs) identified within the geographical region of the NUG (e.g., (MS 2 and BS 21—NUG1), (MS 4, 6, 8 and 10—NUG2) and (MS 12, 14 and BS 23—NUG3))." *Id*. at 6:24-29; *see also* Appx63 at 3:56-60 ("The NUGs represent an area of collected calibration data…"). As seen in the figure, each grid point (or "NUG") is not merely a point—instead, each grid point represents an area of similar calibration data, comprised of network signal information collected or transmitted in that area.

The irregularity in the grid points depicted above is a result of how they are generated. The locations and geographic boundaries of the grid points are not predefined as they would be in a conventional grid. Instead, they are defined based on analysis of the similarity of the calibration data from which they are generated. Appx189 at 10:43-61; *see supra* at 19-22. This analysis involves "increasingly stringent tests of statistical sufficiency" including, for example, clustering tests and probability density functions. Appx189-90 at 10:66-11:6, 12:4-14. Because of this, the grid points "do not necessarily have to be part of a uniform grid and usually will not be uniformly distributed throughout the geographic region." Appx185 at 2:43-

46. Similarly, the characteristics associated with each grid point, which define parameters of the network signals propagating in an area, are also based on the measured calibration data. Appx190 at 12:26-50. Thus, because of how the grid points are generated, their location, shape, and associated characteristics are tailored to an area based on the properties of network signals propagating in that area.

The reason the claimed grid points are not merely points on a conventional grid is tied to the problem they address. As explained above, network signals (*e.g.*, cellular signals) are propagated by transmitters (*e.g.*, cell towers) to enable wireless networks. *See supra* at 12-13. Although not intended or designed for such purpose, these signals can be used opportunistically for geolocation as an alternative or addition to GPS—accordingly, they are sometimes called "signals of opportunity" in the field. *Id*. However, the accuracy and efficiency of geolocation using network signals suffers when transmitters are few and far between, resulting in a sparse "map" of known locations associated with signal information. *See supra* at 13-14. The further a mobile device is from a transmitter, the greater the issue. *Id*. Moreover, these network signals travel irregularly and unpredictably through the environment, especially in the presence of obstructions or buildings.

For example, with reference to the figure above, mobile device 2 is close to base station (or cell tower) 21 whereas mobile device 8 is comparatively far away from any cell tower. Thus, limited signal information may be available to mobile

device 8, making it more difficult for the device to determine its location accurately. Also, even though mobile device 2 is close to cell tower 21, it is relatively far from any other cell tower which can also hamper its ability to geolocate itself.

The invention of the ’753 Patent helps mitigate these issues. As seen in the figure above, the generated grid points fill in the “map” between the cell towers with grid points based on actual measurements of network signals to account for their irregular propagation or the presence of obstructions. This provides the mobile devices with additional information they can select from and use to determine their location, improving the accuracy and efficiency of geolocation. The devices do not have to rely solely on signals from nearby cell towers or attenuated signals from more distant cell towers.

Thus, the district court’s finding that “nothing in the claims requires the grid points to be [] arranged in a ‘denser ‘map’ of known locations” is incorrect. Appx22. That concept is inherent in the claimed grid points—as depicted above—and reflects their primary benefit. Nothing more is required in the claims because “[c]laims need not articulate the advantages of the claimed combinations to be eligible.” *Uniloc*, 957 F.3d at 1309 (rejecting argument that “the claims themselves must expressly mention the [benefits] achieved by the claimed [invention]”).

The approach to geolocation claimed in the ’753 Patent is in stark contrast to conventional approaches. Conventional geolocation systems could attempt to

overcome the limited availability of network signal information by performing complex calculations but this required sophisticated hardware and more processing power. Appx274-75 ¶ 59. Some geolocation systems might forgo using network signals, relying solely on GPS, despite this approach having several drawbacks. *See supra* at 11-12.

Even those prior art geolocation systems using network signals in connection with grids did so with ***conventional*** grids and with points that differ significantly from the grid points claimed in the ’753 Patent. *See supra* at 18-19, 22-24 (describing and showing how the conventional grids of the ’144 Patent and ’966 Patent differ from the “grid” of the ’753 Patent). This is an important distinction because conventional grids are predefined—independently of any calibration data—and thus not tailored to a region or based on network signal propagation in the way the generated grid points of the ’753 Patent are. Put another way, the “grid” of the ’753 Patent does not exist until the claimed grid points are generated, each with a location, boundaries, and characteristics dictated by calibration data comprising measurements of network signals propagating in an area. The size, shape, and spacing of conventional grids and grid points, on the other hand, are set in advance so that they do not depend on such measurements. *See supra* at 19-24. This marked difference further demonstrates the unconventional nature of what is patented in the ’753 Patent.

In sum, the claims are directed not to an abstract idea, but rather to a specific improvement to the technological process of geolocation using network signals that involves novel, unconventional data structures—*i.e.*, the claimed grid points. Such improvements to a technological process are patent-eligible. *See, e.g., Diehr*, 450 U.S. at 187-88 (holding claims reciting an improvement in the rubber curing process patent-eligible); *Core Wireless Licensing S.A.R.L. v. LG Elecs., Inc.*, 880 F.3d 1356, 1362-63 (Fed. Cir. 2018) (holding claims reciting improvement to mobile device user interfaces patent-eligible).

Notably, the Federal Circuit has found that claims directed to improvements to existing technology using specific data structures are patent-eligible. In *Enfish*, claims reciting a system for storing data were found patent-eligible because they were directed to a "specific type of data structure designed to improve the way a computer stores and retrieves data in memory." *Enfish*, 822 F.3d at 1339. In reaching its decision, the Federal Circuit relied heavily on the differences between the claimed self-referential table and conventional databases. *Id*. at 1337 (explaining "the self-referential table functions differently than conventional database structures" and has "benefits over conventional databases"). In *Adasa*, the Federal Circuit found claims "focus[ing] on the data structure of the serial number space" in an RFID transponder to be patent-eligible because the data structure was "designed to enable technological improvements to the commissioning process." *Adasa*, 55 F.4th at 908.

Again, the Federal Circuit focused on how the claimed data structure provided benefits over "RFID tags utilizing conventional data structures." *Id*. at 908-09. The same principle should be applied to find the '753 Patent claims patent-eligible as the claimed grid points are unique data structures—generated in a specific manner (*see supra* at 19-22)—that are used as part of the claimed invention to improve the process of geolocation.

The Federal Circuit has also emphasized that inventions that alter the normal operation of the underlying technology are not abstract. In *DDR Holdings, LLC v. Hotels.com, L.P.*, 773 F.3d 1245 (Fed. Cir. 2014), the Federal Circuit relied on the claimed invention "overrid[ing] the routine and conventional sequence of events ordinarily triggered by the click of a hyperlink" to find claims related to the navigation of websites patent-eligible. *Id*. at 1258-59. The Federal Circuit has relied on the same principle repeatedly in finding claims to be patent-eligible. *SRI*, 930 F.3d at 1304 (holding that claims are patent-eligible, finding they "actually prevent the normal, expected operation of a conventional computer network"). *Uniloc*, 957 F.3d at 1308 ("[T]he claimed invention changes the normal operation of the communication system itself to 'overcome a problem specifically arising in the realm of computer networks.'"). This principle is directly applicable to the '753 Patent claims—as explained above, the invention changes the normal operation of geolocation to overcome problems in the field.

Importantly, the Federal Circuit focuses on whether the claimed invention operates in an unconventional manner ***even if using conventional components***. The Federal Circuit's decision in *Thales* is particularly instructive as the claims related to tracking the position of an object, similar to how the '753 Patent claims relate to determining the location of a mobile device. In *Thales*, the Federal Circuit found claims directed to a "particular configuration of inertial sensors and a particular ***method of using the raw data from the sensors***" patent-eligible because they allowed "more accurately calculat[ing] the position and orientation of an object on a moving platform." *Thales*, 850 F.3d at 1349 (emphasis added). Although the inertial sensors were conventional hardware, the claims were directed to an unconventional use of them that enabled new measurements and new uses of data, resulting in an improvement to existing technology for locating objects. *Id*. at 1345, 1348-49. The Federal Circuit found the claims to be "nearly indistinguishable from the claims at issue in *Diehr*," where the Supreme Court found patent-eligible a computer-controlled process that used an otherwise conventional "temperature measurement" at a specific location to control heating inputs, leading to an improvement to a rubber curing process. *Id.* at 1348 (addressing *Diehr*, 450 U.S. 175 (1981)). The same is true for the '753 Patent claims. Even if the claimed invention employs conventional components—*e.g.*, cell towers and mobile devices—the components and data from them are used in an unconventional way to improve

geolocation, including by collecting calibration data at various points throughout a region to generate a new form of "grid point" whose location and boundaries are based on the data itself rather than a conventional "grid."

In finding the '753 Patent claims to be patent-ineligible, the district court stated that "the claims recite no specific solution to make the alleged improvement concrete" and "the claims do not focus on a specific means or method that would improve the relevant technology." Appx21. As explained above, these erroneous conclusions resulted, in part, from the district court disregarding its claim constructions. *See supra* at 34-40. But the district court's error is also a result of it failing to view the claims in light of the specification, as is required. Indeed, the district court's *Alice* Step One analysis ***does not address the '753 Patent specification at all***, just as it did not address the claim constructions. Appx20-22.

As the Federal Circuit has recognized, the specification plays an important role in understanding the claims for purposes of a § 101 analysis. *Enfish*, 822 F.3d at 1335 ("[T]he 'directed to' inquiry applies a stage-one filter to claims, considered in light of the specification, based on whether "their character as a whole is directed to excluded subject matter."). Because of this, the Federal Circuit has repeatedly relied on the specification of a patent to find claims directed to patentable subject matter under *Alice* Step One. *Packet Intel. LLC v. NetScout Sys., Inc.*, 965 F.3d 1299, 1309 (Fed. Cir. 2020) ("The asserted patents' specifications make clear that the

claimed invention presented a technological solution to a technological problem."); *SRI*, 930 F.3d at 1303 ("The specification bolsters our conclusion that the claims are directed to a technological solution to a technological problem."); *CardioNet*, 955 F.3d at 1370 ("the written description of the '207 patent confirms that the asserted claims are directed to a specific technological improvement"); *Adasa*, 55 F.4th at 908 ("Considered as a whole, and in view of the specification, claim 1 is not directed to an abstract idea."). Indeed, the Federal Circuit has found error in a district court's failure to credit the specification. *CardioNet*, 955 F.3d at 1371 ("[T]he district court erred by disregarding the written description's recitation of the advantages of the claimed invention."). Thus, the district court's failure to consider and credit the '753 Patent specification as part of its *Alice* Step One analysis is error.

It is true that the patent-eligible improvements must be found in the claims and "reliance on the specification must always yield to the claim language." *Chamberlain Grp., Inc. v. Techtronic Indus. Co.*, 935 F.3d 1341, 1346 (Fed. Cir. 2019. However, that is precisely the case here. The '753 Patent claims encompass the unconventional approach to geolocation described above in limitations reciting the generation of grid points—as that term is used in the patent—and the use of those grid points for geolocation. Appx214 at 59:19-31 (reciting "generating one or more sets of grid points for said calibration data" and additional steps of using those grid points in a particular manner for geolocation); *see also* Appx216 at 63:59-67 (same).

Every single aspect of the invention need not be recited in the claims verbatim as long as the claims can be understood to include those aspects when read in view of the specification. In *Packet Intelligence*, the Federal Circuit explained that in finding claims to be patent-eligible in *SRI*, it "relied on statements in the specification that the claimed invention purported to solve weaknesses in the prior art" despite "the *SRI* claims recit[ing] general steps for network monitoring ***with minimal detail present in the claim limitations themselves***." *Packet Intel.*, 965 F.3d at 1309 (discussing *SRI*, 930 F.3d 1295) (emphasis added). Similarly, one of the claims found patent-eligible in *Thales* recited in its entirety:

> A method comprising determining an orientation of an object relative to a moving reference frame based on signals from two inertial sensors mounted respectively on the object and on the moving reference frame.

*Thales*, 850 F.3d at 1345-46. Despite the minimal detail in the claim, the Federal Circuit found it patent-eligible, relying heavily on the context provided by the specification. *See id*. at 1348. As another example, in *Koninklijke KPN N.V. v. Gemalto M2M GmbH*, 942 F.3d 1143 (Fed. Cir. 2019), the Federal Circuit found a dependent claim reciting only "wherein the varying device is further configured to modify the permutation in time" was "sufficiently specific" to be a patent-eligible improvement, explaining that "a review of the specification makes clear that modifying the permutation in time provides [a] technological benefit." *Id*. at 1148, 1150-51.

When understood in light of the specification, the ’753 Patent claims recite a specific improvement to geolocation technology that relies on unconventional data structures. The district court’s finding that the claims lack specificity is only indicative of its own failure to consider the ’753 Patent specification and its claim constructions, which demonstrate the specific nature of the claimed invention. Accordingly, the Federal Circuit should reverse the district court’s decision and find that the ’753 Patent claims are directed to patentable subject matter.

### B. Step Two: The Claims of the ’753 Patent Recite an Inventive Concept

Even if this Court were to accept the district court’s conclusion that the ’753 Patent claims are directed to an abstract idea—which it should not for the reasons above—the claims nevertheless contain an inventive concept, and thus are patent-eligible. The claims recite a specific implementation of geolocation that relies on generating and using the claimed grid points. As explained above in connection with *Alice* Step One, the claimed grid points are not conventional. *See supra* at 40-48. They have specific requirements as described in the specification—and as reflected in the district court’s claim construction opinion—that demonstrate they are unconventional. *Id*. And their unconventionality is even more apparent when compared to conventional grids, as shown above. *See supra* at 18-19, 22-24. Thus, whether the elements of the ’753 Patent claims are considered individually or as an ordered combination, they recite an inventive concept that satisfies *Alice* Step Two.

*Cellspin Soft, Inc. v. Fitbit, Inc.*, 927 F.3d 1306, 1316 (Fed. Cir. 2019) ("An inventive concept reflects something more than the application of an abstract idea using 'well-understood, routine, and conventional activities previously known to the industry.'").

Moreover, given the well-pleaded allegations in Geoscope's complaints, the district court erred in ruling on a Rule 12(c) motion that the '753 Patent claims contain no inventive concept. The *Alice* Step Two inquiry is a question of fact. *Aatrix*, 882 F.3d at 1128. "[F]actual disputes about whether an aspect of the claims is inventive may preclude dismissal at the pleadings stage under § 101." *Cellspin*, 927 F.3d at 1318. Thus, "patentees who adequately allege their claims contain inventive concepts survive a § 101 eligibility analysis" in the Rule 12 context. *Aatrix*, 882 F.3d at 1126-27. This requires courts to consider what is alleged in the complaint—not only what is written in the patent—and, on a Rule 12 motion, take those allegations as true. *Cellspin*, 927 F.3d at 1317 (finding that district court erred by not accepting allegations in the complaint as true and explaining that "in *Aatrix*, [] we repeatedly cited allegations in the *complaint* to conclude that the disputed claims were potentially inventive").

Despite these well-established legal principles, the district court failed to credit the allegations in the complaints regarding inventiveness, leading it to improperly resolve factual disputes against Geoscope. The complaints include

several paragraphs—with references to the specification and file history of the '753 Patent—describing how the claimed invention is unconventional. *See, e.g.,* Appx267-68 ¶¶ 44-45, Appx274-77 ¶¶ 58-63. For example, the complaints allege that that the "inventions of the '753 Patent improved on conventional methods for geolocation using network signals by, *inter alia*, using calibration data to generate additional non-uniform 'grid points,'" allowing the creation of "a more robust and denser 'map' of known locations associated with network signal data that could be used to locate a mobile device." Appx275-76 ¶ 60. "As a result, geolocation need not rely solely on calculations with regard to cell towers, which might be sparse and located far from a mobile device seeking its location." *Id.*; *see also* Appx276-77 ¶¶ 61-63.

***Yet, nowhere in its one-page Alice Step Two analysis did the district court credit, address, or even acknowledge the allegations in Geoscope's complaints.***[8] *See* Appx22-23. On several occasions, the Federal Circuit has found error where a district court failed to credit allegations of inventiveness in a complaint. *Cellspin*, 927 F.3d at 1316-20 (vacating dismissal under § 101 because "[t]he district court erred by not accepting Cellspin's well-pleaded allegations as true with respect to

[8] The district court cited a handful of paragraphs from the complaints in providing background information about the '753 Patent prior to its § 101 analysis, but did not reference or cite these paragraphs—or any others—in connection with its § 101 analysis. Appx19.

whether its patents capture, transfer, and publish data in a way that is plausibly inventive"); *Coop. Ent.*, 50 F.4th at 131-36 (reversing dismissal under § 101 because "the district court erred in discounting Cooperative's plausible allegations"); *Bascom*, 827 F.3d at 1349-52 (vacating dismissal under § 101 because "BASCOM has alleged that an inventive concept can be found in the ordered combination of claim limitations" and "nothing on this record [] refutes those allegations as a matter of law or justifies dismissal"). The Federal Circuit should similarly find error here where the district court's cursory *Alice* Step Two analysis ***entirely ignores the complaints***, and thus could not have credited the well-pleaded allegations therein.

Instead, the district court relied on the same criticism of the claims for *Alice* Step Two that it did for *Alice* Step One—namely, a purported lack of specificity. *See* Appx22-23. This criticism fails for the same reasons explained above. *See supra* at 36-40, 48-51. Additionally, as the Federal Circuit has recognized, as long as the improvements described in the specification are "captured in the claims," there is a "factual dispute regarding whether the invention describes well-understood, routine, and conventional activities" that precludes dismissal under Rule 12. *See Berkheimer v. HP Inc.*, 881 F.3d 1360, 1369 (Fed. Cir. 2018); *see also Cellspin*, 927 F.3d at 1317 ("As long as what makes the claims inventive is recited by the claims, the specification need not expressly list all the reasons why this claimed structure is unconventional."). The '753 Patent claims indisputably include limitations reciting

the generation of grid points from calibration data and the further use of those grid points for geolocation. Appx214 at 59:19-31, Appx216 at 63:59-67. The claimed grid points themselves are inventive and unconventional. Thus, even if the ’753 Patent claims are found to be directed to an abstract idea, they are still patent-eligible under *Alice* Step Two. At a minimum, there is a factual dispute as to whether the claims include an inventive concept that the district court improperly resolved against Geoscope.

In sum, the district court’s § 101 ruling disregards the full claim language, the district court’s own claim constructions, the ’753 Patent specification, and the allegations in Geoscope’s complaints. Because of these oversights, the district court’s ruling rests on an overgeneralization of the ’753 Patent claims that is unsupported by the record evidence. When viewed in the proper § 101 framework, the record confirms that the claims are directed to a patentable improvement to geolocation technology. Accordingly, the Federal Circuit should reverse the district court’s ruling and find that the claims of the ’753 Patent are patent-eligible.

## IV. THE “NON-UNIFORM GRID POINTS” CLAIMS OF THE ’104 PATENT FAMILY ARE PATENT-ELIGIBLE

The district court found that all asserted claims of the ’104 Patent Family are patent-ineligible. Geoscope only appeals the ruling as to certain dependent claims, all of which add the same limitation to the independent claim from which they depend: “wherein said database comprises previously-gathered calibration data for

one or more non-uniform grid points within said region." The appealed claims are claim 2 of the '104 Patent, claim 18 of the '358 Patent, and claims 4 and 26 of the '494 Patent. The district court's § 101 analysis of the independent claims focused on claim 1 of the '494 Patent, reciting:

> 1. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> collecting observed network measurement data, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
>
> modifying said observed network measurement data; and
>
> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Appx108 at 12:10-22. The independent claims from the '104 and '358 Patents are very similar. Appx67 at 11:66-12:15, Appx89 at 12:10-19.

The appealed claims from the '494 Patent are claims 4 and 26 recite:

> 4. The method of claim 1 wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.
>
> 26. The method of claim 25 wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

Appx108 at 12:31-33, Appx109 at 14:24-26. The appealed claims from the ’104 and ’358 Patents are identical except that they depend from different independent claims. Appx67 at 12:16-18; Appx90 at 13:27-29.

The claims of the ’104 Patent Family address a particular problem in geolocation involving disparities between calibration data and observed data caused by “varying conditions and other operational variables” affecting how signals propagate in different environments, resulting in “poor estimated location accuracy.” Appx62 at 1:33-40, Appx66 at 9:35-39, Appx269-70 ¶¶ 49-50. One common reason for this disparity is that calibration data is “typically collected in an outdoor environment” because it is “time-consuming to perform calibration procedures indoors” but geolocation within a building—using observed data collected indoors—is often desirable. Appx62 at 1:24-32, Appx269-70 ¶ 49. Thus, the differences in signal propagation outdoors versus indoors can make it difficult to perform an appropriate comparison of calibration data to observed data for geolocation. *Id*.

To solve this problem, the ’104 Patent Family claims are directed to a specific improvement to geolocation technology involving modifying the observed data measured by a mobile device to eliminate disparities with previously-gathered calibration data. Appx63 at 3:43-49, Appx271-74 ¶¶ 51-56. The specification describes at length what these modifications may entail and how they are performed.

Appx64 at 5:5-45, *id*. at 5:58-6:52, Appx64-65 at 6:53-7:19, Appx271-72 ¶ 51. By using this approach, disparities between calibration data and observed data could be corrected to prevent an "apples and oranges" comparison between the two. On its own, this represents a patent-eligible improvement to the process of geolocation. *See, e.g., Diehr*, 450 U.S. at 187-88 (holding claims reciting an improvement to an existing technological patent-eligible).

The appealed claims, however, go even further by incorporating the use of grid points—the same unconventional data structures discussed with respect to the '753 Patent—to address the sparse "map" problem described above. *See supra* at 14-16, 41-43. As the district court recognized, the term "grid point" has the same meaning in the '753 Patent as it does in the '104 Patent Family. Appx2750-52 (adopting single construction for "grid point" which "appears in several claims of the '104 Patent, '358 Patent, '494 Patent, and '753 Patent"). Thus, the grid points of the appealed claims of the '104 Patent Family have the same specific requirements described above in connection with the '753 Patent—namely, they are (1) generated based on analysis of gathered calibration data and (2) are associated with data that is representative of an area in a particular manner (*i.e.*, based on statistical similarity). *See supra* at 36-38 (citing Appx2751-52). Accordingly, the non-uniform grid points of the appealed claims are unconventional—and in stark contrast to conventional grids—for the same reasons explained above. *See supra* at 40-48

(describing and depicting unconventionality of claimed grid points); *see also supra* at 18-24. Thus, like the ’753 Patent claims, the appealed claims of the ’104 Patent Family are directed to a specific improvement to geolocation technology that uses unconventional data structures—*i.e.*, the claimed non-uniform grid points. At a minimum, the appealed claims of the ’104 Patent Family are patent-eligible for the same reasons the ’753 Patent claims are. And the additional technological improvement they provide in terms of eliminating disparities between calibration data and observed data used for geolocation makes this even clearer.

Although there are differences between the ’753 Patent claims and the ’104 Patent Family appealed claims, that does not change that the latter are directed to patent-eligible improvements. The appealed claims of the ’104 Patent Family recite that the claimed database “comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” Thus, the claims still recite the use of the same “grid points”—as that term is used in all of the related patents—as part of geolocating mobile devices using network signals.

The district court’s analysis of the ’104 Patent Family claims was largely focused on claim 1 of the ’494 Patent. *See generally* Appx10-18. But, critically, the district court recognized that claim 1 of the ’494 Patent is ***not representative*** of the appealed claims reciting “non-uniform grid points.” Appx9 (“[T]he Court finds that claim 1 of the ’494 Patent is not representative of *all* of the asserted claims of the

'104 Patent Family" because, *inter alia*, "the references to … grid points (claim 2 of the '104 Patent, claim 18 of the '358 Patent, and claims 4 and 26 of the '494 Patent) distinguish these claims from claim 1 of the '494 Patent.").

Despite this, the district court's analysis of the appealed claims reciting "non-uniform grid points" is almost non-existent. The entirety of the district court's *Alice* Step One analysis for these claims is reproduced below:

> Finally, the dependent claims (claim 2 of the '104 Patent, claim 18 of the '358 Patent, claim 4 of the '494 Patent, and claim 26 of the '494 Patent) involve gathering calibration data for non-uniform grid points. Geoscope argues (here and with respect to the '753 Patent addressed below) that the "grid point" component is "something new that must be determined from the analysis of calibration data." Opp. at 26 (discussing grid points in the context of the '753 Patent). But these dependent claims invoking grid points merely involve collecting a certain kind of data without requiring a new or improved manner of collecting, using, or creating that data. And, the dependent claims involving grid points do not articulate with specificity *how* the grid points are determined or analyzed.

Appx16-17 (emphasis in original). The entirety of its *Alice* Step Two analysis for these claims is reproduced below:

> With respect to grid points, the Court has already explained that the language of the claims invoking grid points does not specify how grid points are generated or analyzed. Nor do the claims recite using the data in a novel or improved manner.

Appx18.

The district court's conclusions are incorrect for the same reasons described above in connection with the '753 Patent claims—primarily, the district court failed

to appreciate the particular requirements of the claimed grid points despite having acknowledged them during claim construction. *See supra* at 34-40. But these errors are particularly egregious because the district court's analysis is even more cursory for these claims than it was for the '753 Patent claims. Again, the district court ignored its constructions of several terms used in the appealed '104 Patent Family claims, including "calibration data," "observed network measurement data" (from the independent claims), and—importantly—"grid point." Appx2738-42, Appx2750-52. And, just as it did for the '753 Patent claims, the district court ignored the specification of the '104 Patent Family when analyzing the appealed claims. Even if the district court's analysis of the '753 Patent can be interpreted as part of its analysis of the appealed '104 Patent Family claims—because both claim "grid points"—the same fatal flaws persist for the reasons explained above.

Additionally, not only are the claimed non-uniform grid points unconventional, as explained above, but the claimed modification of observed measurement data is unconventional too. Thus, both are inventive concepts in the appealed claims. This particular manner of addressing disparities between calibration data and observed data led to concrete technological benefits including improved geolocation accuracy. Appx274 ¶ 57. And it avoided costly and "time-consuming" alternatives like attempting to collect calibration data indoors. Appx62 at 1:24-32, Appx272-73 ¶ 53. At a minimum, the complaints include well-pleaded

allegations evidencing these benefits and the inventive nature of the claims. Appx269-74 ¶ 48-57. But in its cursory analysis of the appealed claims of the ’104 Patent Family, the district court simply ignored these allegations, which is error.

The appealed claims of the ’104 Patent Family cover patent-eligible improvements to the technological process of geolocation. The district court erred in its superficial analysis of these claims for at least the same reasons it erred in its analysis of the ’753 Patent, including by failing to apply its own claim constructions. Thus, the district court’s ruling should be reversed.

## CONCLUSION

The ’753 Patent claims and the appealed claims of the ’104 Patent Family recite specific technological improvements involving unconventional data structures that solve challenges in the field of geolocation. This is patent-eligible subject matter. The district court’s contrary conclusion was based on disregarding the claim language as construed, the specifications, and the well-pleaded allegations in the complaints. By ignoring this record, the district court improperly oversimplified the claims, running afoul of the Supreme Court’s and Federal Circuit’s § 101 jurisprudence. Accordingly, this Court should reverse the district court’s ruling and hold that these claims are patent-eligible.

Dated: November 17, 2023

Respectfully submitted,

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**2024-1003, 2024-1018**

IN THE

# United States Court of Appeals

**FOR THE FEDERAL CIRCUIT**

GEOSCOPE TECHNOLOGIES PTE. LTD.,

*Plaintiff-Appellant,*

—v.—

GOOGLE LLC, APPLE INC.,

*Defendants-Appellees.*

APPEALS FROM THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF VIRGINIA
IN NOS. 1:22-CV-01331-MSN-JFA, 1:22-CV-01373-MSN-JFA,
JUDGE MICHAEL S. NACHMANOFF

## ADDENDUM

| **Description** | **Pages** |
|---|---|
| Memorandum Opinion *(Geoscope v. Google)* | Appx1–23 |
| Memorandum Opinion *(Geoscope v. Apple*) | Appx24–46 |
| Order *(Geoscope v. Google)* | Appx47 |
| Order *(Geoscope v. Apple)* | Appx48 |
| Judgment *(Geoscope v. Google)* | Appx49 |
| Judgment *(Geoscope v. Apple)* | Appx50 |
| U.S. Patent No. 7,561,104 | Appx51–70 |
| U.S. Patent No. 8,400,358 | Appx71–91 |
| U.S. Patent No. 8,786,494 | Appx92–110 |
| U.S. Patent No. 8,406,753 | Appx111–218 |

IN THE UNITED STATES DISTRICT COURT FOR THE
EASTERN DISTRICT OF VIRGINIA
Alexandria Division

| | |
|---|---|
| GEOSCOPE TECHNOLOGIES PTE. LTD,<br>Plaintiff,<br><br>v.<br><br>GOOGLE LLC,<br>Defendant. | No: 1:22-cv-01331-MSN-JFA |

**MEMORANDUM OPINION**

This matter comes before the Court on the Motion for Judgment on the Pleadings filed by Google LLC. (Dkt. No. 92). Upon consideration of the Motion, and for the reasons set forth below, the Court will grant the Motion.

## I. BACKGROUND

Plaintiff Geoscope Technologies Pte. Ltd. ("Geoscope") is the owner of six patents relating to the geolocation of mobile devices. (Dkt. No. 1) ("Compl." ¶¶ 12–30).[1] Location-based services utilize geographic data to provide information to a user or to perform another function based on the user's location. *Id.* ¶ 36. For mobile devices, location-based services "generally rely on the mobile devices being able to determine their [own] location," also referred to as "geolocation." *Id.* ¶ 39. There are various methods by which a mobile device can geolocate itself, each with its own

[1] The six patents at issue in the Complaint are: U.S. Patent Nos. 7,561,104 ("the '104 Patent"); 8,400,358 ("the '358 Patent"); 8,786,494 ("the '494 Patent"); 8,406,753 ("the '753 Patent); 9,097,784 ("the '784 Patent"); and 8,320,264 ("the '264 Patent"). The '104 Patent, '358 Patent, and '494 Patent share the same specification and are collectively referred to as the '104 Patent Family.

Although the parties' briefing addressed the patent eligibility of the '264 Patent and '784 Patent, the Court, pursuant to a stipulation of partial judgment, subsequently entered judgment of noninfringement of the asserted claims of the '264 Patent and of invalidity of the asserted claim of the '784 Patent (as well as claim 52 if the '358 Patent). (Dkt. No. 118). For that reason, this Opinion only addresses the remaining patents at issue (the '104 Patent Family and the '753 Patent), which are hereinafter referred to as the "Asserted Patents."

drawbacks. *Id.* ¶¶ 39–46. Geoscope alleges that the Asserted Patents "claim novel inventions that address [these] challenges and improve the accuracy, speed, and efficiency of geolocation of mobile devices." *Id.* ¶ 47.

On November 22, 2022, Geoscope filed a Complaint against Defendant Google LLC ("Google") alleging infringement of the Asserted Patents.[2] On July 6, 2023, the Court held a claim construction hearing on ten disputed claim terms (Dkt. No. 99), and entered its order on claim construction on July 19, 2023 (Dkt. No. 105).

On June 27, 2023, Google filed a Motion for Judgment on the Pleadings (Dkt. No. 92) ("Motion") on grounds that each of the Asserted Patents is directed to patent-ineligible subject matter pursuant to 35 U.S.C. § 101. (Dkt. Nos. 92, 93 ("Def. Mem.")). Geoscope filed an opposition to the Motion (Dkt. No. 102 ("Opp.")), and Google filed a reply brief (Dkt. No. 108). The Court heard argument on the Motion on August 11, 2023. (Dkt. No. 112).

Following the hearing and based on the Court's construction of the disputed claim terms, the parties filed a stipulation of (1) judgment of noninfringement of the asserted claims of the '264 Patent, and (2) judgment of invalidity of claim 11 of the '784 Patent and claim 52 of the '358 Patent. (Dkt. No. 117). On September 18, 2023 the Court entered partial judgment of noninfringement and invalidity pursuant to the parties' stipulation. (Dkt. No. 118). Accordingly, the Court only addresses the Motion as it relates to the remaining asserted claims in this action: claims 1 and 2 of the '104 Patent; claims 15 and 18 of the '358 Patent; claims 1, 4, 25, 26, and 35 of the '494 Patent; and claims 1 and 32 of the '753 Patent.

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[2] Upon Google's Rule 12(b)(6) motion and following argument on the matter, the Court dismissed claims of pre-complaint willful and indirect infringement as to the '494 Patent and '784 Patent and denied Google's motion to dismiss the remainder of the Complaint. *See* (Dkt. No. 44).

## II. LEGAL STANDARDS

### A. MOTION FOR JUDGMENT ON THE PLEADINGS

Under Federal Rule of Civil Procedure 12(c), a party may move for judgment on the pleadings after the pleadings are closed. Fed. R. Civ. P. 12(c). A Rule 12(c) motion is reviewed under the same standard as a Rule 12(b)(6) motion. *Drager v. PLIVA USA, Inc.*, 741 F.3d 470, 474 (4th Cir. 2014). "Therefore, a motion for judgment on the pleadings 'should only be granted if, after accepting all well-pleaded allegations in the plaintiff's complaint as true and drawing all reasonable factual inferences from those facts in the plaintiff's favor, it appears certain that the plaintiff cannot prove any set of facts in support of his claim entitling him to relief.'" *Id.* (citing *Edwards v. City of Goldsboro*, 178 F.3d 231, 244 (4th Cir. 1999)).

In the context of patent eligibility under 35 U.S.C. § 101, courts resolve questions of eligibility at the Rule 12 stage when, after drawing all reasonable inferences from the intrinsic record and the Rule 12 record in favor of the non-movant, there is no plausible factual dispute. *Cooperative Ent., Inc. v. Kollective Tech., Inc.*, 50 F.4th 127, 130 (Fed. Cir. 2022); *see also SAP Am., Inc. v. InvestPic, LLC*, 898 F.3d 1161, 1166–67 (Fed. Cir. 2018) (patent eligibility may be resolved on a Rule 12(b)(6) motion "where the undisputed facts, considered under the standards required by that Rule, require a holding of ineligibility under the substantive standards of law"). "[C]onclusory statements regarding eligibility" in a complaint—without supporting factual allegations—need not be accepted and "d[o] not preclude dismissal." *Cisco Sys., Inc. v. Uniloc 2017 LLC*, 813 F. App'x 495, 498–99 (Fed. Cir. 2020). And "a court need not accept as true allegations that contradict matters properly subject to judicial notice or by exhibit, such as the claims and the patent specification." *Secured Mail Sols. LLC v. Universal Wilde, Inc.*, 873 F.3d 905, 912 (Fed. Cir. 2017) (cleaned up).

**B. PATENT ELIGIBILITY**

Section 101 of the Patent Act defines patent-eligible subject matter: A patent may be obtained for "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof." 35 U.S.C. § 101. The provision, however, "contains an important implicit exception[.] Laws of nature, natural phenomena, and abstract ideas are not patentable." *Alice Corp. Pty. Ltd. v. CLS Bank Int'l*, 573 U.S. 208, 216 (2014) (citation omitted). Allowing patent claims for such purported inventions would "impede innovation more than it would promote it." *Mayo Collaborative Servs. v. Prometheus Labs., Inc.*, 566 U.S. 66, 71 (2012). Courts must, however, "tread carefully in construing this exclusionary principle lest it swallow all of patent law." *Alice*, 573 U.S. at 217. Because "all inventions"—at some level—"embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas," "applications of such concepts to a new and useful end . . . remain eligible for patent protection." *Id.* (cleaned up).

To assess whether claims are patent eligible under § 101, courts employ a two-step approach. *See Alice*, 573 U.S. at 218, 221. Under the first step of the inquiry, a court must determine whether a claim is "directed to" a patent-ineligible concept, *i.e.*, a law of nature, natural phenomenon, or abstract idea. At this stage, "[t]he claims are considered in their entirety to ascertain whether their character as a whole is directed to excluded subject matter." *Internet Pats. Corp. v. Active Network, Inc.*, 790 F.3d 1343, 1346 (Fed. Cir. 2015). The Federal Circuit has approached this inquiry "by asking what the patent asserts to be the focus of the claimed advance over the prior art. In conducting that inquiry, [courts] must focus on the language of the [a]sserted [c]laims themselves, considered in light of the specification." *TecSec, Inc. v. Adobe Inc.*, 978 F.3d 1278, 1292 (Fed. Cir. 2020) (cleaned up). As the Federal Circuit has explained, the Supreme Court "has not established a definitive rule to determine what constitutes an 'abstract idea' sufficient to satisfy the [inquiry's] first step"; it is "sufficient to compare claims at issue to those claims already

found to be directed to an abstract idea in previous cases." *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1334 (Fed. Cir. 2016).

If the claims are directed to patent-ineligible subject matter, the inquiry proceeds to the second step. At this step, the court "examine[s] the limitations of the claims to determine whether the claims contain an 'inventive concept' to 'transform' the claimed abstract idea into patent eligible subject matter." *Ultramercial, Inc. v. Hulu, LLC*, 772 F.3d 709, 715 (Fed. Cir. 2014) (quoting *Alice*, 573 U.S. at 221). "The 'inventive concept' may arise in one or more of the individual claim limitations or in the ordered combination of the limitations." *Bascom Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1349 (Fed. Cir. 2016). Here, the court must assess whether the limitations "do more than simply recite a 'well-understood, routine, conventional activity.'" *Universal Secure Registry LLC v. Apple Inc.*, 10 F.4th 1342, 1346 (Fed. Cir. 2021) (quoting *Mayo*, 566 U.S. at 72). Claims using "generic functional language" to achieve their purported solutions without reciting "*how* the desired result is achieved" generally cannot survive step two of the inquiry. *Two-Way Medical Ltd. v. Comcast Cable Commc'ns, LLC*, 874 F.3d 1329, 1339 (Fed. Circ. 2017) (quoting *Elec. Power Grp., LLC v. Alstom S.A.*, 830 F.3d 1350, 1355 (Fed. Cir. 2016)).

## III. ANALYSIS

### A. THE '104 PATENT FAMILY

The '104 Patent Family—the '104 Patent, '358 Patent, and '494 Patent—share the same specification. *See generally* Exs. A–C to Compl. (Dkt. Nos. 1-1–1-3). The patents of the '104 Patent Family generally relate to determining the location of a mobile device by comparing previously-gathered calibration data with observed data that has been modified. Compl. ¶¶ 48, 51. Geoscope's alleged advancement involves the modification of the observed data to account for inconsistencies between sets of data caused by environmental or other factors. *Id.* ¶¶ 44–51.

### 1. Asserted Claims & Representativeness

Geoscope alleges that Google infringes claims 1 and 2 of the ’104 Patent; claims 15 and 18 of the ’358 Patent; and claims 1, 4, 25, 26, and 35 of the ’494 Patent. These claims are recited or described below.

Claim 1 of the ’104 Patent states:

> 1. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a first transmitter and a second transmitter;
>
> collecting observed network measurement data including a first signal characteristic from said first transmitter and a second signal characteristic from said second transmitter;
>
> determining which of said first and second signal characteristics has a greater magnitude;
>
> modifying said observed network measurement data using the greater magnitude signal characteristic; and
>
> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. A to Compl. (Dkt. No. 1-1) (’104 Patent) at 11:65–12:15. Claim 2 of the ’104 Patent recites the method in claim 1 “wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” *Id.* at 12:16–18.

Claim 15 of the ’358 Patent recites:

> 15. A system for determining a location of a mobile station, comprising:
>
> a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> circuitry for collecting observed network measurement data;
>
> circuitry for modifying said observed network measurement data; and
>
> circuitry for comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. B to Compl. (Dkt. No. 1-2) ('358 Patent) at 13:7–17. Claim 18 of the '358 Patent recites the method of claim 15 "wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region." *Id.* at 13:27–29.

Claim 1 of the '494 Patent—which Google argues is representative of the asserted claims of the '104 Patent Family—states:

> 1. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> collecting observed network measurement data, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
>
> modifying said observed network measurement data; and
>
> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. C to Compl. (Dkt. No. 1-3) ('494 Patent) at 12:10–22. Claim 4 of the '494 Patent recites the method of claim 1 "wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region." *Id.* at 12:31–33.

The final independent asserted claim of the '104 Patent Family, claim 25 of the '494 Patent, states:

> 25. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
>
> determining an average value for select ones of said signal characteristics;
>
> modifying said observed network measurement data using said average value; and

> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

'494 Patent at 14:7–23. Claim 26 of the '494 Patent recites the method of claim 25 "wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region." *Id.* at 14:24–26. Finally, claim 35 of the '494 Patent recites the method of claim 25 "wherein at least one of said plurality of transmitters is not a member of said wireless network." *Id.* at 15:4–6.

For the purposes of patent eligibility, a court may "treat a claim as representative . . . if the patentee does not present any meaningful argument for the distinctive significance of any claim limitations not found in the representative claim." *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1365 (Fed. Cir. 2018). Google contends that claim 1 of the '494 Patent is representative of the asserted claims of the '104 Patent Family. As set forth above, claim 1 of the '494 Patent recites a method of "providing" a database of data, "collecting" different data, "modifying" that collected data, and "comparing" data to determine a location. Google argues that the remaining independent claims are "materially the same" to this claim and, at most, "add abstract ideas or well-known and conventional components operating as intended to perform the same method of location determination." Def. Mem. at 6. Google further argues that the dependent claims only add minor limitations related to the data collection or the analysis performed.

Geoscope contests Google's assertion that claim 1 of the '494 Patent is representative, identifying three categories of claims that are distinct from claim 1 of the '494 Patent. *First*, Geoscope argues that certain other asserted claims describe how data is modified by referencing an "average value" (specifically, claims 25, 26, and 35 of the '494 Patent) and the "magnitude" of "signal characteristics," including the greater of two signal characteristics (specifically, claims 1 and 2 of the '104 Patent). Opp. at 23 & n.4. Geoscope argues that because the other asserted claims

of the ’104 Patent Family include these additional limitations that refute Google’s arguments about why the ’104 Patent Family claims are patent ineligible, claim 1 of the ’494 Patent cannot be representative of all asserted claims of the ’104 Patent Family. *Second*, Geoscope identifies claims that recite “non-uniform grid points” as distinct from claim 1 of the ’494 Patent, which does not reference grid points. Opp. at 23. Geoscope does not specifically state in its Opposition which particular claims make such references, but those appear to be claim 2 of the ’104 Patent, claim 18 of the ’358 Patent, and claims 4 and 26 of the ’494 Patent. *Third*, Geoscope argues that dependent claims reciting that one of the data transmitters be outside the network relates to a particular configuration not referenced in claim 1 of the ’494 Patent, and that a new configuration of conventional hardware can be patent eligible. Opp. at 23–24. Again, Geoscope does not identify the particular claims that fall under this third category, but it appears that claim 35 of the ’494 Patent is the only remaining asserted claim that refers to such outside-the-network transmitters.

Although many of the asserted claims of the ’104 Patent Family are “substantially similar” and are all linked to the “same abstract idea” of data collection, modification, and analysis, *see Content Extraction & Transmission LLC v. Wells Fargo Bank, Nat. Ass’n*, 776 F.3d 1343, 1348 (Fed. Cir. 2014), the Court finds that claim 1 of the ’494 Patent is not representative of *all* of the asserted claims of the ’104 Patent Family. In particular, the references to mathematical components (claims 25, 26, and 35 of the ’494 Patent and claims 1 and 2 of the ’104 Patent); circuitry (claims 15 and 18 of the ’358 Patent); and grid points (claim 2 of the ’104 Patent, claim 18 of the ’358 Patent, and claims 4 and 26 of the ’494 Patent) distinguish these claims from claim 1 of the ’494 Patent. In the *Alice* analysis below, the Court will therefore address the distinguishing characteristics of these claims and why—notwithstanding these distinctions—the asserted claims are still not patent eligible.

### 2. *Alice* Analysis

#### a. Step One

The first step of the *Alice* test entails determining whether the claims at issue are directed to an abstract idea. At this step, the Court considers "what the patent asserts to be the focus of the claimed advance over the prior art." *Yu v. Apple, Inc.*, 1 F.4th 1040, 1043 (Fed. Cir. 2021). The Court finds that the asserted claims of the '104 Patent Family are directed to the abstract idea of determining location based on data. Specifically, the claims are directed to providing a database, collecting data, modifying the collected data, and comparing the modified data against the database to determine a location of a mobile device.

Looking first at claim 1 of the '494 Patent, which Google contends is representative of the asserted claims of the '104 Patent Family, the principal steps of that claim are both broad and generic. The claim recites a method for "determining a location of a mobile station" by (1) "providing a database" of previously-collected data; (2) "collecting" observed network measurement data, (3) "modifying" that data; and (4) "comparing" the modified data with the database. But the basic function of determining location based on the collection and analysis of data has been performed by humans throughout history. This function is fundamentally a "method of organizing human activity," which courts have characterized as abstract. *See Alice*, 573 U.S. at 220; *BSG Tech LLC v. BuySeasons, Inc.*, 899 F.3d 1281, 1285 (Fed. Cir. 2018) ("fundamental, long-prevalent practice[s]" and "well-established method[s] of organizing activity" qualify as abstract ideas). And the specification recognizes that doing so in the context of mobile devices is *not* novel. *See* (Dkt. No. 1-3) ('494 Patent) at 1:28–31.

Indeed, the Federal Circuit has consistently concluded that claims requiring the mere collection, analysis, and outputting of data are directed to patent-ineligible subject matter. *E.g.*, *Int'l Bus. Machines Corp. v. Zillow Grp., Inc.*, 50 F.4th 1371, 1378 (Fed. Cir. 2022) (claims

abstract where computer employed in normal manner to "collect[] information" and to "comprehend[] the meaning of that collected information[] and indication of the results"); *Elec. Power Grp.*, 830 F.3d at 1353–54 (claims focused on "collecting information, analyzing it, and displaying certain results of the collection and analysis" considered abstract); *Content Extraction*, 776 F.3d at 1347 (abstract concepts of "data collection, recognition, and storage" were functions that had always been performed by humans); *Interval Licensing LLC v. AOL, Inc.*, 896 F.3d 1335, 1345 (Fed. Cir. 2018) (displaying data considered abstract); *Automated Tracking Sols., LLC v. Coca-Cola Co.*, 723 F. App'x 989, 991 (Fed. Cir. 2018) (claims concerning "collecting data from sensors, analyzing that data, and determining results based on the analysis of data" directed to an abstract idea); *cf. GeoComply Solutions Inc. v. Xpoint Services LLC*, No. 22-cv-1273, 2023 WL 1927393, at *6 (D. Del. Feb. 10, 2023) (Bryson, J.) (claims directed to abstract idea of "determining the location of a device based on geolocation information and programs present on the device" held patent ineligible). So too here. As evidenced by claim 1 of the '494 Patent, the asserted claims of the '104 Patent Family focus on the abstract concept of data collection and modification for the purpose of geolocation of mobile devices.

Geoscope relies in large part on *Thales Visionix Inc. v. United States*, 850 F.3d 1343 (Fed. Cir. 2017), to argue that the asserted claims of the '104 Patent Family are not directed to an abstract idea. Opp. at 14–15. In *Thales*, the Federal Circuit held that claims related to a "system for tracking the motion of an object relative to a moving reference frame" were patent eligible because they were not merely directed to the abstract idea of "using mathematical equations for determining the relative position of a moving object to a moving reference frame," but rather "to systems and methods that use inertial sensors in a non-conventional manner to reduce errors in measuring the relative position and orientation of a moving object on a moving reference frame." *Id.* at 1344, 1348–49 (cleaned up). In doing so, the Federal Circuit also observed that "[t]he claims specify a

particular configuration of inertial sensors and a particular method of using the raw data from the sensors in order to more accurately calculate the position and orientation of an object on a moving platform." *Id.* at 1349. Geoscope argues that "[l]ike the new use of 'raw data from the sensors' in *Thales*, the 'modifying' in the '104 Patent Family constituted a new use of data that directly addressed a technological problem in conventional geolocation systems." Opp. at 13. Although the Federal Circuit indeed observed that the claims in *Thales* specified a particular method of "using raw data," the patent eligibility of the claimed invention in *Thales* turned not on the mere *use* of raw data in a new setting but also on the unconventional *arrangement* of sensors—a "new and useful technique" for using sensors that more efficiently tracked an object on a moving platform. 850 F.3d at 1348–49. The asserted claims here do not require the use of technology in an unconventional manner. Nor do they require an unconventional configuration of components. At bottom, unlike in *Thales*, Geoscope's purported technological improvement is simply the modification of data, which is itself an abstract idea that is not patent eligible.

That is not to say that patents involving the geolocation of mobile devices are categorically patent ineligible; rather, such patents must recite a specific solution to make the alleged improvement sufficiently concrete in order to confer eligibility under § 101. *See Hawk Tech. Sys., LLC v. Castle Retail, LLC*, 60 F.4th 1349, 1358 (Fed. Cir. 2023); *Realtime Data LLC v. Array Networks Inc.*, Nos. 2021-2251, 2021-2291, 2023 WL 4924814, at *8 (Fed. Cir. Aug. 2, 2023) (finding claims related to compression of data abstract where "none of the claims at issue specifies any particular technique to carry out the compression of data" and merely "call[] for unparticularized analysis of data and achievement of general goals"). Geoscope argues that the asserted claims of the '104 Patent Family are directed to "specific technological improvements to geolocation systems that change how geolocation is performed," Opp. at 12–13, but the asserted claims proffer no such concrete improvement. The core of the purported advancement to

"geolocation systems" is the modification of data—under Geoscope's theory, the asserted claims improve on conventional geolocation methods by "modifying the observed data to account for" disparities between calibration data (typically collected outdoors) with data collected indoors, as well other disparities caused by various environmental factors. *See id.* at 3–4, 11 (citing Compl., '104 Patent).

Geoscope's argument, however, is undermined by the fact that the language of the asserted claims themselves are not so limited. Although Geoscope identifies some language in the specification and the Complaint about the elimination of disparities in collecting and comparing indoor and outdoor data, *see* Opp. at 11, its arguments are "not tethered to the *asserted claims*" themselves. *See Trinity InfoMedia, LLC v. Covalent, Inc.*, 72 F.4th 1355, 1364 (Fed. Cir. 2023). The Court's analysis must focus on the asserted claims, considering their character "as a whole" and "in light of the specification." *Chamberlain Group, Inc. v. Techtronic Indus. Co.*, 935 F.3d 1341, 1346 (Fed. Cir. 2019). While the specification "may help illuminate the true focus of a claim, when analyzing patent eligibility, reliance on the specification must always yield to the claim language in identifying that focus.'" *Id.* (citing *ChargePoint, Inc. v. SemaConnect, Inc.*, 920 F.3d 759, 766 (Fed. Cir. 2019)). Here, the language of the claims themselves do not recite any specific improvement. Rather, as discussed above, the language of the "modifying" step of claim 1 of the '494 Patent is written in extremely broad terms: it simply recites a method whereby one must "modify[] said observed network measurement data," without any specificity as to *how* to carry out the "modifying" function. Geoscope cannot use the specification to "import details from the specification if those details are not claimed." *ChargePoint*, 920 F.3d at 769 ("Even a specification full of technical details about a physical invention may nonetheless conclude with claims that claim nothing more than the broad law or abstract idea underlying the claims, thus preempting all use of that law or idea.").

Moreover, and notwithstanding that Geoscope's alleged improvements do not appear in the language of the asserted claims themselves, neither the specification nor the language of the claims require a specific technological improvement to geolocation systems that would push the claims into the realm of the non-abstract. To be patent eligible, improvements to a technological process must be directed to "non-abstract improvements to the functionality of" the existing technological process. *See Uniloc USA, Inc. v. LG Elecs. USA, Inc.*, 957 F.3d 1303, 1309 (Fed. Cir. 2020). But here, Geoscope's claimed advance—modifying data—is itself an abstract concept. *See Univ. of Fla. Res. Found., Inc. v. Gen. Elec. Co.*, 916 F.3d 1363, 1368 (Fed. Cir. 2019); *Intellectual Ventures I LLC v. Capital One Fin. Corp.*, 850 F.3d 1332, 1340 (Fed. Cir. 2017) (holding ineligible claims directed to the "abstract idea of collecting, displaying, and manipulating data"); *Elec. Power Grp.*, 830 F.3d at 1355 ("Merely requiring the selection and manipulation of information . . . by itself does not transform the otherwise-abstract processes of information collection and analysis"). Claims that add the abstract concept of modifying or manipulating data do not involve an improvement to the functionality of a technological process. *See Simio, LLC v. FlexSim Software Prods., Inc.*, 983 F.3d 1353, 1361 (Fed. Cir. 2020).

Geoscope argues that claims merely *involving* data manipulation and transmission but that are not *directed to* these concepts may nonetheless be patent eligible, citing *Uniloc v. LG*, 957 F.3d 1303. Opp. at 17–18. In *Uniloc*, the specification explained that with conventional communication systems, a "primary station alternates between polling and sending inquiry messages." 957 F.3d at 1308. Unlike the asserted claims here, the claims at issue in *Uniloc* "recite[d] a specific improvement in the functionality of the communication system itself." *Id.* at 1309. Specifically, those claims required "adding to each inquiry message prior to transmission an additional data field for polling at least one secondary station"—something the Federal Circuit described as a fundamental "change [to] the normal operation" of the communication system itself because that

the primary stations could simultaneously send inquiry and polling transmissions. *Id.* at 1307–08. Therefore, the claimed invention in *Uniloc*, although involving the addition of a data field, offered a precise and concrete technological solution to an existing technology in that it "enable[d] the communication system to accommodate additional devices, such as battery-operated secondary stations, without compromising performance." *Id.* at 1308. Here, the asserted claims do not recite any such specific or concrete improvement to the method of geolocation. They merely require one to "modify[ ] observed network measurement data," '494 Patent at 12:19, without a fundamental "change" to the "normal operation" of any existing technology.

Claim 1 of the '494 Patent therefore fails to recite *how* the invention purportedly improves geolocation systems beyond merely modifying or manipulating data. Where a claim fails to "recite a specific solution to make the alleged improvement . . . concrete and at most recite[s] abstract data manipulation," the claim is directed to an abstract idea. *See Hawk*, 60 F.4th at 1358 (cleaned up). Here, the claims are written with a "result-oriented generality" that amount to a "mere implementation of an abstract idea." *See id.* (cleaned up); *see also GeoComply*, 2023 WL 1927393, at *5 ("in determining whether a method claim is directed to an abstract idea, the Federal Circuit has focused on whether the claim is purely functional in nature or is sufficiently concrete or specific to be directed to a patent-eligible process rather than a patent-eligible result"). The preemptive scope of claim 1 of the '494 Patent is apparent; by its plain language, the claim would accord patent protection to any method of collecting, modifying, and comparing data in order to determine the location of a mobile device. *See GeoComply*, 2023 WL 1927393, at *9 (asserted claims that are "sweeping" with a "broad preemptive scope" "lend[] further support to the proposition that the asserted claims are directed to an abstract idea").

Beyond claim 1 of the '494 Patent, none of the other asserted claims of the '104 Patent Family save Geoscope from this conclusion. The three remaining independent asserted claims add

abstract ideas or well-known or conventional components used in a normal manner. In addition to requiring the collection, modification, and comparison of data, claim 1 of the '104 Patent requires determining the greater of two signal characteristics and then using—without specifying *how* that data is used—the larger one in the modifying data step. Claim 25 of the '494 patent recites a method for analyzing the data to compute the average of different signal characteristics and using—again, in no specified way—that average in the modifying step. These mathematical concepts do not change the focus of the claims, as they are themselves abstract and patent ineligible. *See In re Bd. of Trustees of Leland Stanford Junior Univ.*, 991 F.3d 1245, 1250 (Fed. Cir. 2021) ("Courts have long held that mathematical algorithms for performing calculations, without more, are patent ineligible under § 101."). The third of the remaining independent asserted claims, claim 15 of the '358 Patent, recites a system that "collect[s]," "modif[ies]," and "compar[es]" data but requires the use of generic "circuitry."[3] Circuitry, however, is conventional computer technology. The claims do not recite a method to use circuitry in an unconventional manner. Claim 15 therefore relies "on a process that qualifies as an 'abstract idea' for which computers are invoked merely as a tool." *Customedia Techs., LLC v. Dish Network Corp.*, 951 F.3d 1359, 1365 (Fed. Cir. 2020).

Finally, the dependent claims (claim 2 of the '104 Patent, claim 18 of the '358 Patent, claim 4 of the '494 Patent, and claim 26 of the '494 Patent) involve gathering calibration data for non-uniform grid points. Geoscope argues (here and with respect to the '753 Patent addressed below) that the "grid point" component is "something new that must be determined from the analysis of calibration data." Opp. at 26 (discussing grid points in the context of the '753 Patent). But these

[3] Nor does claim 35 of the '494 Patent, which recites the method of claim 25 "wherein at least one of said plurality of transmitters is not a member of said wireless network," alter the analysis. Geoscope has not pointed to any plausible allegation or fact in the intrinsic record that merely placing the transmitters outside the network is an unconventional configuration. *See* Opp. at 23–24.

dependent claims invoking grid points merely involve collecting a certain kind of data without requiring a new or improved manner of collecting, using, or creating that data. And, the dependent claims involving grid points do not articulate with specificity *how* the grid points are determined or analyzed. The Court therefore finds the asserted claims of the ’104 Patent Family to be directed to the abstract idea of determining location based on data.

**b. Step Two**

Because the asserted claims of the ’104 Patent Family are directed to patent-ineligible subject matter, the Court now proceeds to step two of the *Alice* test. At this step, the Court “examine[s] the limitations of the claims to determine whether [they] contain an inventive concept to transform the claimed abstract idea into patent eligible subject matter.” *Ultramercial*, 772 F.3d at 715 (cleaned up). The Court may find the “inventive concept” in one or more of the individual claim limitations or in the ordered combination of the limitations. *Bascom*, 827 F.3d at 1349. The “inventive concept” can also be found in “the non-conventional and non-generic arrangement of known, conventional pieces.” *Id.* at 1350.

Here, none of the asserted claims of the ’104 Patent Family advance an inventive concept amounting to “significantly more” than the abstract idea. *See ChargePoint*, 920 F.3d at 773. As explained in the step one analysis, each of the independent claims involve some limitation related to the collection, modification, or comparison of data—each of which are abstract ideas in themselves that cannot supply the inventive concept. Geoscope primarily argues that the modification of the data supplies the inventive concept, arguing that “modifying observed network measurement data was not well-understood, routine, or conventional, and constitutes an inventive concept.” *See* Opp. at 20. But Geoscope fails to identify facts showing that the step of “modifying” data as recited in the claims requires any specific technological improvement. Nor does the combination of these steps supply the inventive concept. Here, the steps as set forth in the asserted

claims add nothing that is not already present when considered separately. "Adding one abstract idea . . . to another abstract idea . . . does not render [a] claim non-abstract." *ChargePoint*, 920 F.3d at 771.

And, as also discussed above, that some of the asserted claims include references to (1) simple mathematical concepts, (2) grid points, (3) "circuitry," or (4) requiring transmitters to be outside the network is insufficient to confer the inventive concept necessary for patent eligibility. Regarding the claims that require the determination of the greater of two signal characteristics or the average of different signal characteristics, those claims vaguely reference the mathematical concepts but fail to recite *how* those concepts are employed. And, using simple mathematical concepts, such as those invoked in these claims, is itself an abstract idea insufficient to confer an inventive concept. *See Stanford*, 991 F.3d at 1251. With respect to grid points, the Court has already explained that the language of the claims invoking grid points does not specify how grid points are generated or analyzed. Nor do the claims recite using the data in a novel or improved manner. Regarding claims reciting "circuitry," these claims simply employ well-known and conventional data or components in a conventional manner. Finally, that claim 35 of the '494 Patent requires a data transmitter to be outside the network is insufficient to confer the inventive concept. These transmitters are generic, conventional tools employed in a conventional manner and without any specific technological improvement.

The asserted claims therefore do no more than combine known techniques that yield only expected results. Geoscope identifies no claim elements that amount to "significantly more" than the abstract idea of determining location based on data. Accordingly, the Court finds that there is no inventive concept sufficient to confer patent eligibility at step two of the *Alice* test, and the asserted claims of the '104 Patent Family are patent ineligible under § 101.

**B. ’753 PATENT**

**1. Asserted Claims**

The ’753 Patent involves purported improvements to methods of geolocation using “grid points” based on calibration data. Compl. ¶ 58. The claimed invention uses calibration data to generate and use grid points, including “non-uniform grid points” (“NUGs”), that can be selected from and used to determine the location of a mobile device. *Id.* ¶ 60; ’753 Patent at 9:34–48. Geoscope asserts that this process led to a “more robust and denser ‘map’ of known locations” that could be used to locate a mobile device. Compl. ¶ 60. Geoscope alleges Google has infringed claims 1 and 32 of the ’753 Patent, which are independent claims.

Claim 1 of the ’753 Patent is a method claim reciting:

> 1. A method of determining the location of a mobile device in a geographic region comprising the steps of:
>
> (a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;
>
> (b) generating one or more sets of grid points for said calibration data;
>
> (c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;
>
> (d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;
>
> (e) selecting a set of grid points as a function of predetermined criteria; and
>
> (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points

Ex. D to Compl. (Dkt. No. 1-4) (’753 Patent) at 59:13–31.

Claim 32 is a system claim that states:

> 32. A system for determining the location of a mobile device in a geographic region comprising:
>
> (a) a database; and

(b) a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in said geographic region, said calibration data and network measurement report having at least one characterizing parameter and said processor is programmed to:

(i) generate one or more sets of grid points for said calibration data,

(ii) evaluate said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters,

(iii) select a set of grid points as a function of a predetermined criteria, and

(iv) determine the location of a mobile device in said geographic region as a function of said selected set.

*Id.* at 63:49–67.

### 2. *Alice* Analysis

#### a. Step One

The asserted claims of the ’753 Patent are directed to the abstract idea of determining an unknown location by comparing information about known locations organized in a database against measurements from a mobile device. In essence, the asserted claims of the ’753 Patent merely purport to collect and organize data in a reference database and to compare data received from an unknown location to data in the selected database of known locations. The discussion of patent eligibility as to the asserted claims of the ’753 Patent overlap considerably with the ’104 Patent Family analysis. As discussed with respect to the data collection claims of the ’104 Patent Family, such claims are directed to abstract ideas that are patent ineligible under § 101. *See supra* Section III.A.2.a; *see also Content Extraction*, 776 F.3d at 1347 (claims directed to “1) collecting data, 2) recognizing certain data within the collected data set, and 3) storing that recognized data in a memory” held abstract); *Sanderling Mgmt. Ltd. v. Snap Inc.*, 65 F.4th 698, 701–03 (Fed. Cir. 2023) (claims requiring “matching a GPS location indication with a geographic location” directed

to abstract idea); *CalAmp Wireless Networks Corp. v. ORBCOMM, Inc.*, 233 F. Supp. 3d 509, 512–13 (E.D. Va. 2017) (claim involving "assessing the current location of [an] object" is "an abstract idea"). The claims at issue in *Sanderling* are similar to those at issue with the '753 Patent: the claims in *Sanderling* required "access[ing] a database storing" various functions associated with "a geographic location," "receiving . . . a Global Positioning System (GPS) location indication from each of a plurality of mobile devices," "matching . . . each said GPS location indication with said geographic location" in the database, and then selecting a "digital image processing function" for use based on the geographic location. 65 F.4th at 701–02. The Federal Circuit held these claims to be directed to the abstract idea "'of providing information—in this case, a processing function—based on meeting a condition,' *e.g.*, matching a GPS location indication with a geographic location." 65 F.4th at 703. Relying primarily on the Federal Circuit decisions in *Enfish*, 822 F.3d 1327, and *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295, 1303–04 (Fed. Cir. 2019), Geoscope argues that a patent is not ineligible under § 101 just because a claimed invention involves the analysis or organization of data, so long it is directed to improving a technological process or system. *See* Opp. 26–28. Geoscope is not wrong: That a claimed invention operates by analyzing or organizing data does not immediately doom it to patent ineligibility under § 101. Rather, the element of data analysis or organization must be directed to a *specific* solution to make an alleged improvement concrete and that would "transform [the] claim from one claiming only a result to one claiming a way of achieving it." *See SAP*, 898 F.3d at 1167; *see also Hawk*, 60 F.4th at 1358.

Here, Geoscope focuses primarily on the generation of grid points as supplying a specific technological improvement. Opp. at 26–29. But the language of the asserted claims does not support Geoscope's position, as the claims recite no specific solution to make the alleged improvement concrete. That is, the claims do not focus on a specific means or method that would improve the relevant technology. Rather, the limitations of the asserted claims are drafted at a high

level of generality that they are themselves directed at abstract concepts. And each of Geoscope's assertions regarding the novelty of grid points or the execution of the asserted claims advanced by Geoscope are not supported by the claims; indeed, nothing in the claims requires the grid points to be (1) arranged in a "denser 'map' of known locations," Opp. at 25; (2) "determined from the analysis of calibration data," *id.* at 26–27; or (3) organized in any specific format, *id.* at 28.

This is where the claims of the inventions in *Enfish* and *SRI* diverge from those at issue here. Whereas the asserted claims of the '753 Patent simply recite "generating one or more grid points," the claims in *Enfish* and *SRI* described in detail "a specific improvement."[4] *See Enfish*, 822 F.3d at 1336. In *Enfish*, the claims were "specifically directed to a *self-referential* table for a computer database," an improvement that the Federal Circuit emphasized was "reflected in [the] claim language." *Id.* at 1337. The claims laid out a "four-step algorithm" for creating and organizing such a table. *Id.* And in *SRI*, the claims were directed to an improvement in computer technology because the claims "recite[d] using network monitors to detect suspicious network activity based on analysis of network traffic data, generating reports of that suspicious activity, and integrating those reports using hierarchical monitors." 930 F.3d at 1303. As described above, the asserted claims of the '753 Patent recite no such comparable specific improvement. Accordingly, the Court finds that the asserted claims of the '753 Patent are directed to an abstract idea.

**b. Step Two**

Finding the asserted claims of the '753 Patent to be directed to an abstract idea, the Court must assess whether there exists an "inventive concept" sufficient to confer patent eligibility. The Court finds that the claims are deficient in this regard too. The claims here do not require "a new

[4] For the same reasons, *Adasa Inc. v. Avery Dennison Corp.*, 55 F.4th 900, 908 (Fed. Cir. 2022) and *Trustees of Columbia University in City of N.Y. v. Symantec Corp.*, 425 F. Supp. 3d 601, 616 (E.D. Va. 2019), on which Geoscope also rely, are distinguishable.

source or type of information, or new techniques for analyzing it." *Elec. Power Grp.*, 830 F.3d at 1355. Here, the limitations of the asserted claims fail to address with any specificity *how* the purported functions are performed such that the Court would consider it to constitute an "inventive concept." For instance, claim 1 recites a method that includes "generating one or more sets of grid points" without providing any limitation on *how* the grid points are generated. It also recites a method that includes "evaluating said at least one network measurement report with each of said sets of grid points." But this limitation merely requires performing the basic function of comparing data. Each of the limitations of the asserted claims is broadly written, providing no boundaries or guidance on what that function is or how it is to be performed. And claim 32 applies the method of claim 1 to a "system" and adds to the claim two components—a "database" and a "processor." But a database adds nothing to the inventiveness of the claimed invention. And a processor that receives data and is "programmed" to generate and evaluate data is well-known, conventional, and generic technology that does not transform the claims into an inventive concept. *See Elec. Power*, 830 F.3d at 1356. Accordingly, there being no inventive concept, the Court finds that the asserted claims of the '753 Patent are patent ineligible under § 101.

## IV. CONCLUSION

For the reasons set forth above, the Court will grant Defendant Google's Motion for Judgment on the Pleadings (Dkt. No. 92) in an order to be issued with this Memorandum Opinion.

/s/
Hon. Michael S. Nachmanoff
United States District Judge

Alexandria, Virginia
September 18, 2023

IN THE UNITED STATES DISTRICT COURT FOR THE
EASTERN DISTRICT OF VIRGINIA
Alexandria Division

| | |
|---|---|
| GEOSCOPE TECHNOLOGIES PTE. LTD,<br>Plaintiff,<br><br>v.<br><br>APPLE INC.,<br>Defendant. | No: 1:22-cv-01373-MSN-JFA |

**MEMORANDUM OPINION**

This matter comes before the Court on the Motion for Judgment on the Pleadings filed by Apple Inc. (Dkt. No. 82). Upon consideration of the Motion, and for the reasons set forth below, the Court will grant the Motion.

## I. BACKGROUND

Plaintiff Geoscope Technologies Pte. Ltd. ("Geoscope") is the owner of six patents relating to the geolocation of mobile devices. (Dkt. No. 1) ("Compl." ¶¶ 12–30).[1] Location-based services utilize geographic data to provide information to a user or to perform another function based on the user's location. *Id.* ¶ 36. For mobile devices, location-based services "generally rely on the mobile devices being able to determine their [own] location," also referred to as "geolocation." *Id.* ¶ 39. There are various methods by which a mobile device can geolocate itself, each with its own

[1] The six patents at issue in the Complaint are: U.S. Patent Nos. 7,561,104 ("the '104 Patent"); 8,400,358 ("the '358 Patent"); 8,786,494 ("the '494 Patent"); 8,406,753 ("the '753 Patent); 9,097,784 ("the '784 Patent"); and 8,320,264 ("the '264 Patent"). The '104 Patent, '358 Patent, and '494 Patent share the same specification and are collectively referred to as the '104 Patent Family.

Although the parties' briefing addressed the patent eligibility of the '264 Patent and '784 Patent, the Court, pursuant to a stipulation of partial judgment, subsequently entered judgment of noninfringement of the asserted claims of the '264 Patent and of invalidity of the asserted claim of the '784 Patent (as well as claim 52 if the '358 Patent). (Dkt. No. 107). For that reason, this Opinion only addresses the remaining patents at issue (the '104 Patent Family and the '753 Patent), which are hereinafter referred to as the "Asserted Patents."

drawbacks. *Id.* ¶¶ 39–46. Geoscope alleges that the Asserted Patents "claim novel inventions that address [these] challenges and improve the accuracy, speed, and efficiency of geolocation of mobile devices." *Id.* ¶ 47.

On December 1, 2022, Geoscope filed a Complaint against Defendant Apple Inc. ("Apple") alleging infringement of the Asserted Patents. On July 6, 2023, the Court held a claim construction hearing on ten disputed claim terms (Dkt. No. 88), and entered its order on claim construction on July 19, 2023 (Dkt. No. 92).

On June 27, 2023, Apple filed a Motion for Judgment on the Pleadings (Dkt. No. 82) ("Motion") on grounds that each of the Asserted Patents is directed to patent-ineligible subject matter pursuant to 35 U.S.C. § 101. (Dkt. Nos. 82, 83 ("Def. Mem.")). Geoscope filed an opposition to the Motion (Dkt. No. 90 ("Opp.")), and Apple filed a reply brief (Dkt. No. 93). The Court heard argument on the Motion on August 11, 2023. (Dkt. No. 100).

Following the hearing and based on the Court's construction of the disputed claim terms, the parties filed a stipulation of (1) judgment of noninfringement of the asserted claims of the '264 Patent, and (2) judgment of invalidity of claim 11 of the '784 Patent and claim 52 of the '358 Patent. (Dkt. No. 103). On September 18, 2023 the Court entered partial judgment of noninfringement and invalidity pursuant to the parties' stipulation. (Dkt. No. 107). Accordingly, the Court only addresses the Motion as it relates to the remaining asserted claims in this action: claims 1 and 2 of the '104 Patent; claims 15 and 18 of the '358 Patent; claims 1, 4, 25, 26, and 35 of the '494 Patent; and claims 1 and 32 of the '753 Patent.

## II. LEGAL STANDARDS

### A. MOTION FOR JUDGMENT ON THE PLEADINGS

Under Federal Rule of Civil Procedure 12(c), a party may move for judgment on the pleadings after the pleadings are closed. Fed. R. Civ. P. 12(c). A Rule 12(c) motion is reviewed

under the same standard as a Rule 12(b)(6) motion. *Drager v. PLIVA USA, Inc.*, 741 F.3d 470, 474 (4th Cir. 2014). "Therefore, a motion for judgment on the pleadings 'should only be granted if, after accepting all well-pleaded allegations in the plaintiff's complaint as true and drawing all reasonable factual inferences from those facts in the plaintiff's favor, it appears certain that the plaintiff cannot prove any set of facts in support of his claim entitling him to relief.'" *Id.* (citing *Edwards v. City of Goldsboro*, 178 F.3d 231, 244 (4th Cir. 1999)).

In the context of patent eligibility under 35 U.S.C. § 101, courts resolve questions of eligibility at the Rule 12 stage when, after drawing all reasonable inferences from the intrinsic record and the Rule 12 record in favor of the non-movant, there is no plausible factual dispute. *Cooperative Ent., Inc. v. Kollective Tech., Inc.*, 50 F.4th 127, 130 (Fed. Cir. 2022); *see also SAP Am., Inc. v. InvestPic, LLC*, 898 F.3d 1161, 1166–67 (Fed. Cir. 2018) (patent eligibility may be resolved on a Rule 12(b)(6) motion "where the undisputed facts, considered under the standards required by that Rule, require a holding of ineligibility under the substantive standards of law"). "[C]onclusory statements regarding eligibility" in a complaint—without supporting factual allegations—need not be accepted and "d[o] not preclude dismissal." *Cisco Sys., Inc. v. Uniloc 2017 LLC*, 813 F. App'x 495, 498–99 (Fed. Cir. 2020). And "a court need not accept as true allegations that contradict matters properly subject to judicial notice or by exhibit, such as the claims and the patent specification." *Secured Mail Sols. LLC v. Universal Wilde, Inc.*, 873 F.3d 905, 912 (Fed. Cir. 2017) (cleaned up).

**B. PATENT ELIGIBILITY**

Section 101 of the Patent Act defines patent-eligible subject matter: A patent may be obtained for "any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof." 35 U.S.C. § 101. The provision, however, "contains an important implicit exception[.] Laws of nature, natural phenomena, and abstract ideas are not

patentable." *Alice Corp. Pty. Ltd. v. CLS Bank Int'l*, 573 U.S. 208, 216 (2014) (citation omitted). Allowing patent claims for such purported inventions would "impede innovation more than it would promote it." *Mayo Collaborative Servs. v. Prometheus Labs., Inc.*, 566 U.S. 66, 71 (2012). Courts must, however, "tread carefully in construing this exclusionary principle lest it swallow all of patent law." *Alice*, 573 U.S. at 217. Because "all inventions"—at some level—"embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas," "applications of such concepts to a new and useful end . . . remain eligible for patent protection." *Id.* (cleaned up).

To assess whether claims are patent eligible under § 101, courts employ a two-step approach. *See Alice*, 573 U.S. at 218, 221. Under the first step of the inquiry, a court must determine whether a claim is "directed to" a patent-ineligible concept, *i.e.*, a law of nature, natural phenomenon, or abstract idea. At this stage, "[t]he claims are considered in their entirety to ascertain whether their character as a whole is directed to excluded subject matter." *Internet Pats. Corp. v. Active Network, Inc.*, 790 F.3d 1343, 1346 (Fed. Cir. 2015). The Federal Circuit has approached this inquiry "by asking what the patent asserts to be the focus of the claimed advance over the prior art. In conducting that inquiry, [courts] must focus on the language of the [a]sserted [c]laims themselves, considered in light of the specification." *TecSec, Inc. v. Adobe Inc.*, 978 F.3d 1278, 1292 (Fed. Cir. 2020) (cleaned up). As the Federal Circuit has explained, the Supreme Court "has not established a definitive rule to determine what constitutes an 'abstract idea' sufficient to satisfy the [inquiry's] first step"; it is "sufficient to compare claims at issue to those claims already found to be directed to an abstract idea in previous cases." *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1334 (Fed. Cir. 2016).

If the claims are directed to patent-ineligible subject matter, the inquiry proceeds to the second step. At this step, the court "examine[s] the limitations of the claims to determine whether the claims contain an 'inventive concept' to 'transform' the claimed abstract idea into patent

eligible subject matter." *Ultramercial, Inc. v. Hulu, LLC*, 772 F.3d 709, 715 (Fed. Cir. 2014) (quoting *Alice*, 573 U.S. at 221). "The 'inventive concept' may arise in one or more of the individual claim limitations or in the ordered combination of the limitations." *Bascom Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1349 (Fed. Cir. 2016). Here, the court must assess whether the limitations "do more than simply recite a 'well-understood, routine, conventional activity.'" *Universal Secure Registry LLC v. Apple Inc.*, 10 F.4th 1342, 1346 (Fed. Cir. 2021) (quoting *Mayo*, 566 U.S. at 72). Claims using "generic functional language" to achieve their purported solutions without reciting "*how* the desired result is achieved" generally cannot survive step two of the inquiry. *Two-Way Medical Ltd. v. Comcast Cable Commc'ns, LLC*, 874 F.3d 1329, 1339 (Fed. Circ. 2017) (quoting *Elec. Power Grp., LLC v. Alstom S.A.*, 830 F.3d 1350, 1355 (Fed. Cir. 2016)).

## III. ANALYSIS

### A. THE '104 PATENT FAMILY

The '104 Patent Family—the '104 Patent, '358 Patent, and '494 Patent—share the same specification. *See generally* Exs. A–C to Compl. (Dkt. Nos. 1-1–1-3). The patents of the '104 Patent Family generally relate to determining the location of a mobile device by comparing previously-gathered calibration data with observed data that has been modified. Compl. ¶¶ 48, 51. Geoscope's alleged advancement involves the modification of the observed data to account for inconsistencies between sets of data caused by environmental or other factors. *Id.* ¶¶ 44–51.

#### 1. Asserted Claims & Representativeness

Geoscope alleges that Apple infringes claims 1 and 2 of the '104 Patent; claims 15 and 18 of the '358 Patent; and claims 1, 4, 25, 26, and 35 of the '494 Patent. These claims are recited or described below.

Claim 1 of the ’104 Patent states:

1. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a first transmitter and a second transmitter;

collecting observed network measurement data including a first signal characteristic from said first transmitter and a second signal characteristic from said second transmitter;

determining which of said first and second signal characteristics has a greater magnitude;

modifying said observed network measurement data using the greater magnitude signal characteristic; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. A to Compl. (Dkt. No. 1-1) (’104 Patent) at 11:65–12:15. Claim 2 of the ’104 Patent recites the method in claim 1 “wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” *Id.* at 12:16–18.

Claim 15 of the ’358 Patent recites:

15. A system for determining a location of a mobile station, comprising:

a database of previously-gathered calibration data for a predetermined region in a wireless network;

circuitry for collecting observed network measurement data;

circuitry for modifying said observed network measurement data; and

circuitry for comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. B to Compl. (Dkt. No. 1-2) (’358 Patent) at 13:7–17. Claim 18 of the ’358 Patent recites the method of claim 15 “wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” *Id.* at 13:27–29.

Claim 1 of the ’494 Patent—which Apple argues is representative of the asserted claims of the ’104 Patent Family—states:

> 1. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> collecting observed network measurement data, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
>
> modifying said observed network measurement data; and
>
> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

Ex. C to Compl. (Dkt. No. 1-3) (’494 Patent) at 12:10–22. Claim 4 of the ’494 Patent recites the method of claim 1 “wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” *Id.* at 12:31–33.

The final independent asserted claim of the ’104 Patent Family, claim 25 of the ’494 Patent, states:

> 25. A method for determining a location of a mobile station, comprising:
>
> providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
>
> collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
>
> determining an average value for select ones of said signal characteristics;
>
> modifying said observed network measurement data using said average value; and
>
> comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

’494 Patent at 14:7–23. Claim 26 of the ’494 Patent recites the method of claim 25 “wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.” *Id.* at 14:24–26. Finally, claim 35 of the ’494 Patent recites the method of claim 25 “wherein at least one of said plurality of transmitters is not a member of said wireless network.” *Id.* at 15:4–6.

For the purposes of patent eligibility, a court may “treat a claim as representative . . . if the patentee does not present any meaningful argument for the distinctive significance of any claim limitations not found in the representative claim.” *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1365 (Fed. Cir. 2018). Apple contends that claim 1 of the ’494 Patent is representative of the asserted claims of the ’104 Patent Family. As set forth above, claim 1 of the ’494 Patent recites a method of “providing” a database of data, “collecting” different data, “modifying” that collected data, and “comparing” data to determine a location. Apple argues that the remaining independent claims are “materially the same” to this claim and, at most, “add abstract ideas or well-known and conventional components operating as intended to perform the same method of location determination.” Def. Mem. at 6. Apple further argues that the dependent claims only add minor limitations related to the data collection or the analysis performed.

Geoscope contests Apple’s assertion that claim 1 of the ’494 Patent is representative, identifying three categories of claims that are distinct from claim 1 of the ’494 Patent. *First*, Geoscope argues that certain other asserted claims describe how data is modified by referencing an “average value” (specifically, claims 25, 26, and 35 of the ’494 Patent) and the “magnitude” of “signal characteristics,” including the greater of two signal characteristics (specifically, claims 1 and 2 of the ’104 Patent). Opp. at 23 & n.4. Geoscope argues that because the other asserted claims of the ’104 Patent Family include these additional limitations that refute Apple’s arguments about why the ’104 Patent Family claims are patent ineligible, claim 1 of the ’494 Patent cannot be

representative of all asserted claims of the '104 Patent Family. *Second*, Geoscope identifies claims that recite "non-uniform grid points" as distinct from claim 1 of the '494 Patent, which does not reference grid points. Opp. at 23. Geoscope does not specifically state in its Opposition which particular claims make such references, but those appear to be claim 2 of the '104 Patent, claim 18 of the '358 Patent, and claims 4 and 26 of the '494 Patent. *Third*, Geoscope argues that dependent claims reciting that one of the data transmitters be outside the network relates to a particular configuration not referenced in claim 1 of the '494 Patent, and that a new configuration of conventional hardware can be patent eligible. Opp. at 23–24. Again, Geoscope does not identify the particular claims that fall under this third category, but it appears that claim 35 of the '494 Patent is the only remaining asserted claim that refers to such outside-the-network transmitters.

Although many of the asserted claims of the '104 Patent Family are "substantially similar" and are all linked to the "same abstract idea" of data collection, modification, and analysis, *see Content Extraction & Transmission LLC v. Wells Fargo Bank, Nat. Ass'n*, 776 F.3d 1343, 1348 (Fed. Cir. 2014), the Court finds that claim 1 of the '494 Patent is not representative of *all* of the asserted claims of the '104 Patent Family. In particular, the references to mathematical components (claims 25, 26, and 35 of the '494 Patent and claims 1 and 2 of the '104 Patent); circuitry (claims 15 and 18 of the '358 Patent); and grid points (claim 2 of the '104 Patent, claim 18 of the '358 Patent, and claims 4 and 26 of the '494 Patent) distinguish these claims from claim 1 of the '494 Patent. In the *Alice* analysis below, the Court will therefore address the distinguishing characteristics of these claims and why—notwithstanding these distinctions—the asserted claims are still not patent eligible.

### 2. *Alice* Analysis

#### a. Step One

The first step of the *Alice* test entails determining whether the claims at issue are directed to an abstract idea. At this step, the Court considers "what the patent asserts to be the focus of the claimed advance over the prior art." *Yu v. Apple, Inc.*, 1 F.4th 1040, 1043 (Fed. Cir. 2021). The Court finds that the asserted claims of the '104 Patent Family are directed to the abstract idea of determining location based on data. Specifically, the claims are directed to providing a database, collecting data, modifying the collected data, and comparing the modified data against the database to determine a location of a mobile device.

Looking first at claim 1 of the '494 Patent, which Apple contends is representative of the asserted claims of the '104 Patent Family, the principal steps of that claim are both broad and generic. The claim recites a method for "determining a location of a mobile station" by (1) "providing a database" of previously-collected data; (2) "collecting" observed network measurement data, (3) "modifying" that data; and (4) "comparing" the modified data with the database. But the basic function of determining location based on the collection and analysis of data has been performed by humans throughout history. This function is fundamentally a "method of organizing human activity," which courts have characterized as abstract. *See Alice*, 573 U.S. at 220; *BSG Tech LLC v. BuySeasons, Inc.*, 899 F.3d 1281, 1285 (Fed. Cir. 2018) ("fundamental, long-prevalent practice[s]" and "well-established method[s] of organizing activity" qualify as abstract ideas). And the specification recognizes that doing so in the context of mobile devices is *not* novel. *See* (Dkt. No. 1-3) ('494 Patent) at 1:28–31.

Indeed, the Federal Circuit has consistently concluded that claims requiring the mere collection, analysis, and outputting of data are directed to patent-ineligible subject matter. *E.g.*, *Int'l Bus. Machines Corp. v. Zillow Grp., Inc.*, 50 F.4th 1371, 1378 (Fed. Cir. 2022) (claims

abstract where computer employed in normal manner to "collect[] information" and to "comprehend[] the meaning of that collected information[] and indication of the results"); *Elec. Power Grp.*, 830 F.3d at 1353–54 (claims focused on "collecting information, analyzing it, and displaying certain results of the collection and analysis" considered abstract); *Content Extraction*, 776 F.3d at 1347 (abstract concepts of "data collection, recognition, and storage" were functions that had always been performed by humans); *Interval Licensing LLC v. AOL, Inc.*, 896 F.3d 1335, 1345 (Fed. Cir. 2018) (displaying data considered abstract); *Automated Tracking Sols., LLC v. Coca-Cola Co.*, 723 F. App'x 989, 991 (Fed. Cir. 2018) (claims concerning "collecting data from sensors, analyzing that data, and determining results based on the analysis of data" directed to an abstract idea); *cf. GeoComply Solutions Inc. v. Xpoint Services LLC*, No. 22-cv-1273, 2023 WL 1927393, at *6 (D. Del. Feb. 10, 2023) (Bryson, J.) (claims directed to abstract idea of "determining the location of a device based on geolocation information and programs present on the device" held patent ineligible). So too here. As evidenced by claim 1 of the '494 Patent, the asserted claims of the '104 Patent Family focus on the abstract concept of data collection and modification for the purpose of geolocation of mobile devices.

Geoscope relies in large part on *Thales Visionix Inc. v. United States*, 850 F.3d 1343 (Fed. Cir. 2017), to argue that the asserted claims of the '104 Patent Family are not directed to an abstract idea. Opp. at 14–15. In *Thales*, the Federal Circuit held that claims related to a "system for tracking the motion of an object relative to a moving reference frame" were patent eligible because they were not merely directed to the abstract idea of "using mathematical equations for determining the relative position of a moving object to a moving reference frame," but rather "to systems and methods that use inertial sensors in a non-conventional manner to reduce errors in measuring the relative position and orientation of a moving object on a moving reference frame." *Id.* at 1344, 1348–49 (cleaned up). In doing so, the Federal Circuit also observed that "[t]he claims specify a

particular configuration of inertial sensors and a particular method of using the raw data from the sensors in order to more accurately calculate the position and orientation of an object on a moving platform." *Id.* at 1349. Geoscope argues that "[l]ike the new use of 'raw data from the sensors' in *Thales*, the 'modifying' in the '104 Patent Family constituted a new use of data that directly addressed a technological problem in conventional geolocation systems." Opp. at 13. Although the Federal Circuit indeed observed that the claims in *Thales* specified a particular method of "using raw data," the patent eligibility of the claimed invention in *Thales* turned not on the mere *use* of raw data in a new setting but also on the unconventional *arrangement* of sensors—a "new and useful technique" for using sensors that more efficiently tracked an object on a moving platform. 850 F.3d at 1348–49. The asserted claims here do not require the use of technology in an unconventional manner. Nor do they require an unconventional configuration of components. At bottom, unlike in *Thales*, Geoscope's purported technological improvement is simply the modification of data, which is itself an abstract idea that is not patent eligible.

That is not to say that patents involving the geolocation of mobile devices are categorically patent ineligible; rather, such patents must recite a specific solution to make the alleged improvement sufficiently concrete in order to confer eligibility under § 101. *See Hawk Tech. Sys., LLC v. Castle Retail, LLC*, 60 F.4th 1349, 1358 (Fed. Cir. 2023); *Realtime Data LLC v. Array Networks Inc.*, Nos. 2021-2251, 2021-2291, 2023 WL 4924814, at *8 (Fed. Cir. Aug. 2, 2023) (finding claims related to compression of data abstract where "none of the claims at issue specifies any particular technique to carry out the compression of data" and merely "call[] for unparticularized analysis of data and achievement of general goals"). Geoscope argues that the asserted claims of the '104 Patent Family are directed to "specific technological improvements to geolocation systems that change how geolocation is performed," Opp. at 12–13, but the asserted claims proffer no such concrete improvement. The core of the purported advancement to

"geolocation systems" is the modification of data—under Geoscope's theory, the asserted claims improve on conventional geolocation methods by "modifying the observed data to account for" disparities between calibration data (typically collected outdoors) with data collected indoors, as well other disparities caused by various environmental factors. *See id.* at 3–4, 11 (citing Compl., '104 Patent).

Geoscope's argument, however, is undermined by the fact that the language of the asserted claims themselves are not so limited. Although Geoscope identifies some language in the specification and the Complaint about the elimination of disparities in collecting and comparing indoor and outdoor data, *see* Opp. at 11, its arguments are "not tethered to the *asserted claims*" themselves. *See Trinity InfoMedia, LLC v. Covalent, Inc.*, 72 F.4th 1355, 1364 (Fed. Cir. 2023). The Court's analysis must focus on the asserted claims, considering their character "as a whole" and "in light of the specification." *Chamberlain Group, Inc. v. Techtronic Indus. Co.*, 935 F.3d 1341, 1346 (Fed. Cir. 2019). While the specification "may help illuminate the true focus of a claim, when analyzing patent eligibility, reliance on the specification must always yield to the claim language in identifying that focus.'" *Id.* (citing *ChargePoint, Inc. v. SemaConnect, Inc.*, 920 F.3d 759, 766 (Fed. Cir. 2019)). Here, the language of the claims themselves do not recite any specific improvement. Rather, as discussed above, the language of the "modifying" step of claim 1 of the '494 Patent is written in extremely broad terms: it simply recites a method whereby one must "modify[] said observed network measurement data," without any specificity as to *how* to carry out the "modifying" function. Geoscope cannot use the specification to "import details from the specification if those details are not claimed." *ChargePoint*, 920 F.3d at 769 ("Even a specification full of technical details about a physical invention may nonetheless conclude with claims that claim nothing more than the broad law or abstract idea underlying the claims, thus preempting all use of that law or idea.").

Moreover, and notwithstanding that Geoscope's alleged improvements do not appear in the language of the asserted claims themselves, neither the specification nor the language of the claims require a specific technological improvement to geolocation systems that would push the claims into the realm of the non-abstract. To be patent eligible, improvements to a technological process must be directed to "non-abstract improvements to the functionality of" the existing technological process. *See Uniloc USA, Inc. v. LG Elecs. USA, Inc.*, 957 F.3d 1303, 1309 (Fed. Cir. 2020). But here, Geoscope's claimed advance—modifying data—is itself an abstract concept. *See Univ. of Fla. Res. Found., Inc. v. Gen. Elec. Co.*, 916 F.3d 1363, 1368 (Fed. Cir. 2019); *Intellectual Ventures I LLC v. Capital One Fin. Corp.*, 850 F.3d 1332, 1340 (Fed. Cir. 2017) (holding ineligible claims directed to the "abstract idea of collecting, displaying, and manipulating data"); *Elec. Power Grp.*, 830 F.3d at 1355 ("Merely requiring the selection and manipulation of information . . . by itself does not transform the otherwise-abstract processes of information collection and analysis"). Claims that add the abstract concept of modifying or manipulating data do not involve an improvement to the functionality of a technological process. *See Simio, LLC v. FlexSim Software Prods., Inc.*, 983 F.3d 1353, 1361 (Fed. Cir. 2020).

Geoscope argues that claims merely *involving* data manipulation and transmission but that are not *directed to* these concepts may nonetheless be patent eligible, citing *Uniloc v. LG*, 957 F.3d 1303. Opp. at 17–18. In *Uniloc*, the specification explained that with conventional communication systems, a "primary station alternates between polling and sending inquiry messages." 957 F.3d at 1308. Unlike the asserted claims here, the claims at issue in *Uniloc* "recite[d] a specific improvement in the functionality of the communication system itself." *Id.* at 1309. Specifically, those claims required "adding to each inquiry message prior to transmission an additional data field for polling at least one secondary station"—something the Federal Circuit described as a fundamental "change [to] the normal operation" of the communication system itself because that

the primary stations could simultaneously send inquiry and polling transmissions. *Id.* at 1307–08. Therefore, the claimed invention in *Uniloc*, although involving the addition of a data field, offered a precise and concrete technological solution to an existing technology in that it "enable[d] the communication system to accommodate additional devices, such as battery-operated secondary stations, without compromising performance." *Id.* at 1308. Here, the asserted claims do not recite any such specific or concrete improvement to the method of geolocation. They merely require one to "modify[ ] observed network measurement data," '494 Patent at 12:19, without a fundamental "change" to the "normal operation" of any existing technology.

Claim 1 of the '494 Patent therefore fails to recite *how* the invention purportedly improves geolocation systems beyond merely modifying or manipulating data. Where a claim fails to "recite a specific solution to make the alleged improvement . . . concrete and at most recite[s] abstract data manipulation," the claim is directed to an abstract idea. *See Hawk*, 60 F.4th at 1358 (cleaned up). Here, the claims are written with a "result-oriented generality" that amount to a "mere implementation of an abstract idea." *See id.* (cleaned up); *see also GeoComply*, 2023 WL 1927393, at *5 ("in determining whether a method claim is directed to an abstract idea, the Federal Circuit has focused on whether the claim is purely functional in nature or is sufficiently concrete or specific to be directed to a patent-eligible process rather than a patent-eligible result"). The preemptive scope of claim 1 of the '494 Patent is apparent; by its plain language, the claim would accord patent protection to any method of collecting, modifying, and comparing data in order to determine the location of a mobile device. *See GeoComply*, 2023 WL 1927393, at *9 (asserted claims that are "sweeping" with a "broad preemptive scope" "lend[] further support to the proposition that the asserted claims are directed to an abstract idea").

Beyond claim 1 of the '494 Patent, none of the other asserted claims of the '104 Patent Family save Geoscope from this conclusion. The three remaining independent asserted claims add

abstract ideas or well-known or conventional components used in a normal manner. In addition to requiring the collection, modification, and comparison of data, claim 1 of the ’104 Patent requires determining the greater of two signal characteristics and then using—without specifying *how* that data is used—the larger one in the modifying data step. Claim 25 of the ’494 patent recites a method for analyzing the data to compute the average of different signal characteristics and using—again, in no specified way—that average in the modifying step. These mathematical concepts do not change the focus of the claims, as they are themselves abstract and patent ineligible. *See In re Bd. of Trustees of Leland Stanford Junior Univ.*, 991 F.3d 1245, 1250 (Fed. Cir. 2021) (“Courts have long held that mathematical algorithms for performing calculations, without more, are patent ineligible under § 101.”). The third of the remaining independent asserted claims, claim 15 of the ’358 Patent, recites a system that “collect[s],” “modif[ies],” and “compar[es]” data but requires the use of generic “circuitry.”[2] Circuitry, however, is conventional computer technology. The claims do not recite a method to use circuitry in an unconventional manner. Claim 15 therefore relies “on a process that qualifies as an ‘abstract idea’ for which computers are invoked merely as a tool.” *Customedia Techs., LLC v. Dish Network Corp.*, 951 F.3d 1359, 1365 (Fed. Cir. 2020).

Finally, the dependent claims (claim 2 of the ’104 Patent, claim 18 of the ’358 Patent, claim 4 of the ’494 Patent, and claim 26 of the ’494 Patent) involve gathering calibration data for non-uniform grid points. Geoscope argues (here and with respect to the ’753 Patent addressed below) that the “grid point” component is “something new that must be determined from the analysis of calibration data.” Opp. at 26 (discussing grid points in the context of the ’753 Patent). But these

[2] Nor does claim 35 of the ’494 Patent, which recites the method of claim 25 “wherein at least one of said plurality of transmitters is not a member of said wireless network,” alter the analysis. Geoscope has not pointed to any plausible allegation or fact in the intrinsic record that merely placing the transmitters outside the network is an unconventional configuration. *See* Opp. at 23–24.

dependent claims invoking grid points merely involve collecting a certain kind of data without requiring a new or improved manner of collecting, using, or creating that data. And, the dependent claims involving grid points do not articulate with specificity *how* the grid points are determined or analyzed. The Court therefore finds the asserted claims of the '104 Patent Family to be directed to the abstract idea of determining location based on data.

**b. Step Two**

Because the asserted claims of the '104 Patent Family are directed to patent-ineligible subject matter, the Court now proceeds to step two of the *Alice* test. At this step, the Court "examine[s] the limitations of the claims to determine whether [they] contain an inventive concept to transform the claimed abstract idea into patent eligible subject matter." *Ultramercial*, 772 F.3d at 715 (cleaned up). The Court may find the "inventive concept" in one or more of the individual claim limitations or in the ordered combination of the limitations. *Bascom*, 827 F.3d at 1349. The "inventive concept" can also be found in "the non-conventional and non-generic arrangement of known, conventional pieces." *Id.* at 1350.

Here, none of the asserted claims of the '104 Patent Family advance an inventive concept amounting to "significantly more" than the abstract idea. *See ChargePoint*, 920 F.3d at 773. As explained in the step one analysis, each of the independent claims involve some limitation related to the collection, modification, or comparison of data—each of which are abstract ideas in themselves that cannot supply the inventive concept. Geoscope primarily argues that the modification of the data supplies the inventive concept, arguing that "modifying observed network measurement data was not well-understood, routine, or conventional, and constitutes an inventive concept." *See* Opp. at 20. But Geoscope fails to identify facts showing that the step of "modifying" data as recited in the claims requires any specific technological improvement. Nor does the combination of these steps supply the inventive concept. Here, the steps as set forth in the asserted

claims add nothing that is not already present when considered separately. "Adding one abstract idea . . . to another abstract idea . . . does not render [a] claim non-abstract." *ChargePoint*, 920 F.3d at 771.

And, as also discussed above, that some of the asserted claims include references to (1) simple mathematical concepts, (2) grid points, (3) "circuitry," or (4) requiring transmitters to be outside the network is insufficient to confer the inventive concept necessary for patent eligibility. Regarding the claims that require the determination of the greater of two signal characteristics or the average of different signal characteristics, those claims vaguely reference the mathematical concepts but fail to recite *how* those concepts are employed. And, using simple mathematical concepts, such as those invoked in these claims, is itself an abstract idea insufficient to confer an inventive concept. *See Stanford*, 991 F.3d at 1251. With respect to grid points, the Court has already explained that the language of the claims invoking grid points does not specify how grid points are generated or analyzed. Nor do the claims recite using the data in a novel or improved manner. Regarding claims reciting "circuitry," these claims simply employ well-known and conventional data or components in a conventional manner. Finally, that claim 35 of the '494 Patent requires a data transmitter to be outside the network is insufficient to confer the inventive concept. These transmitters are generic, conventional tools employed in a conventional manner and without any specific technological improvement.

The asserted claims therefore do no more than combine known techniques that yield only expected results. Geoscope identifies no claim elements that amount to "significantly more" than the abstract idea of determining location based on data. Accordingly, the Court finds that there is no inventive concept sufficient to confer patent eligibility at step two of the *Alice* test, and the asserted claims of the '104 Patent Family are patent ineligible under § 101.

**B. ’753 PATENT**

**1. Asserted Claims**

The ’753 Patent involves purported improvements to methods of geolocation using “grid points” based on calibration data. Compl. ¶ 58. The claimed invention uses calibration data to generate and use grid points, including “non-uniform grid points” (“NUGs”), that can be selected from and used to determine the location of a mobile device. *Id.* ¶ 60; ’753 Patent at 9:34–48. Geoscope asserts that this process led to a “more robust and denser ‘map’ of known locations” that could be used to locate a mobile device. Compl. ¶ 60. Geoscope alleges Apple has infringed claims 1 and 32 of the ’753 Patent, which are independent claims.

Claim 1 of the ’753 Patent is a method claim reciting:

> 1. A method of determining the location of a mobile device in a geographic region comprising the steps of:
>
> (a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;
>
> (b) generating one or more sets of grid points for said calibration data;
>
> (c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;
>
> (d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;
>
> (e) selecting a set of grid points as a function of predetermined criteria; and
>
> (f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points

Ex. D to Compl. (Dkt. No. 1-4) (’753 Patent) at 59:13–31.

Claim 32 is a system claim that states:

> 32. A system for determining the location of a mobile device in a geographic region comprising:
>
> (a) a database; and

(b) a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in said geographic region, said calibration data and network measurement report having at least one characterizing parameter and said processor is programmed to:

(i) generate one or more sets of grid points for said calibration data,

(ii) evaluate said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters,

(iii) select a set of grid points as a function of a predetermined criteria, and

(iv) determine the location of a mobile device in said geographic region as a function of said selected set.

*Id.* at 63:49–67.

### 2. *Alice* Analysis

#### a. Step One

The asserted claims of the ’753 Patent are directed to the abstract idea of determining an unknown location by comparing information about known locations organized in a database against measurements from a mobile device. In essence, the asserted claims of the ’753 Patent merely purport to collect and organize data in a reference database and to compare data received from an unknown location to data in the selected database of known locations. The discussion of patent eligibility as to the asserted claims of the ’753 Patent overlap considerably with the ’104 Patent Family analysis. As discussed with respect to the data collection claims of the ’104 Patent Family, such claims are directed to abstract ideas that are patent ineligible under § 101. *See supra* Section III.A.2.a; *see also Content Extraction*, 776 F.3d at 1347 (claims directed to “1) collecting data, 2) recognizing certain data within the collected data set, and 3) storing that recognized data in a memory” held abstract); *Sanderling Mgmt. Ltd. v. Snap Inc.*, 65 F.4th 698, 701–03 (Fed. Cir. 2023) (claims requiring “matching a GPS location indication with a geographic location” directed

to abstract idea); *CalAmp Wireless Networks Corp. v. ORBCOMM, Inc.*, 233 F. Supp. 3d 509, 512–13 (E.D. Va. 2017) (claim involving "assessing the current location of [an] object" is "an abstract idea"). The claims at issue in *Sanderling* are similar to those at issue with the '753 Patent: the claims in *Sanderling* required "access[ing] a database storing" various functions associated with "a geographic location," "receiving . . . a Global Positioning System (GPS) location indication from each of a plurality of mobile devices," "matching . . . each said GPS location indication with said geographic location" in the database, and then selecting a "digital image processing function" for use based on the geographic location. 65 F.4th at 701–02. The Federal Circuit held these claims to be directed to the abstract idea "'of providing information—in this case, a processing function—based on meeting a condition,' *e.g.*, matching a GPS location indication with a geographic location." 65 F.4th at 703. Relying primarily on the Federal Circuit decisions in *Enfish*, 822 F.3d 1327, and *SRI Int'l, Inc. v. Cisco Sys., Inc.*, 930 F.3d 1295, 1303–04 (Fed. Cir. 2019), Geoscope argues that a patent is not ineligible under § 101 just because a claimed invention involves the analysis or organization of data, so long it is directed to improving a technological process or system. *See* Opp. 26–28. Geoscope is not wrong: That a claimed invention operates by analyzing or organizing data does not immediately doom it to patent ineligibility under § 101. Rather, the element of data analysis or organization must be directed to a *specific* solution to make an alleged improvement concrete and that would "transform [the] claim from one claiming only a result to one claiming a way of achieving it." *See SAP*, 898 F.3d at 1167; *see also Hawk*, 60 F.4th at 1358.

Here, Geoscope focuses primarily on the generation of grid points as supplying a specific technological improvement. Opp. at 26–29. But the language of the asserted claims does not support Geoscope's position, as the claims recite no specific solution to make the alleged improvement concrete. That is, the claims do not focus on a specific means or method that would improve the relevant technology. Rather, the limitations of the asserted claims are drafted at a high

level of generality that they are themselves directed at abstract concepts. And each of Geoscope's assertions regarding the novelty of grid points or the execution of the asserted claims advanced by Geoscope are not supported by the claims; indeed, nothing in the claims requires the grid points to be (1) arranged in a "denser 'map' of known locations," Opp. at 25; (2) "determined from the analysis of calibration data," *id.* at 26–27; or (3) organized in any specific format, *id.* at 28.

This is where the claims of the inventions in *Enfish* and *SRI* diverge from those at issue here. Whereas the asserted claims of the '753 Patent simply recite "generating one or more grid points," the claims in *Enfish* and *SRI* described in detail "a specific improvement."[3] *See Enfish*, 822 F.3d at 1336. In *Enfish*, the claims were "specifically directed to a *self-referential* table for a computer database," an improvement that the Federal Circuit emphasized was "reflected in [the] claim language." *Id.* at 1337. The claims laid out a "four-step algorithm" for creating and organizing such a table. *Id.* And in *SRI*, the claims were directed to an improvement in computer technology because the claims "recite[d] using network monitors to detect suspicious network activity based on analysis of network traffic data, generating reports of that suspicious activity, and integrating those reports using hierarchical monitors." 930 F.3d at 1303. As described above, the asserted claims of the '753 Patent recite no such comparable specific improvement. Accordingly, the Court finds that the asserted claims of the '753 Patent are directed to an abstract idea.

**b. Step Two**

Finding the asserted claims of the '753 Patent to be directed to an abstract idea, the Court must assess whether there exists an "inventive concept" sufficient to confer patent eligibility. The Court finds that the claims are deficient in this regard too. The claims here do not require "a new

[3] For the same reasons, *Adasa Inc. v. Avery Dennison Corp.*, 55 F.4th 900, 908 (Fed. Cir. 2022) and *Trustees of Columbia University in City of N.Y. v. Symantec Corp.*, 425 F. Supp. 3d 601, 616 (E.D. Va. 2019), on which Geoscope also rely, are distinguishable.

source or type of information, or new techniques for analyzing it." *Elec. Power Grp.*, 830 F.3d at 1355. Here, the limitations of the asserted claims fail to address with any specificity *how* the purported functions are performed such that the Court would consider it to constitute an "inventive concept." For instance, claim 1 recites a method that includes "generating one or more sets of grid points" without providing any limitation on *how* the grid points are generated. It also recites a method that includes "evaluating said at least one network measurement report with each of said sets of grid points." But this limitation merely requires performing the basic function of comparing data. Each of the limitations of the asserted claims is broadly written, providing no boundaries or guidance on what that function is or how it is to be performed. And claim 32 applies the method of claim 1 to a "system" and adds to the claim two components—a "database" and a "processor." But a database adds nothing to the inventiveness of the claimed invention. And a processor that receives data and is "programmed" to generate and evaluate data is well-known, conventional, and generic technology that does not transform the claims into an inventive concept. *See Elec. Power*, 830 F.3d at 1356. Accordingly, there being no inventive concept, the Court finds that the asserted claims of the '753 Patent are patent ineligible under § 101.

## IV. CONCLUSION

For the reasons set forth above, the Court will grant Defendant Apple's Motion for Judgment on the Pleadings (Dkt. No. 82) in an order to be issued with this Memorandum Opinion.

/s/

Hon. Michael S. Nachmanoff
United States District Judge

Alexandria, Virginia
September 18, 2023

IN THE UNITED STATES DISTRICT COURT FOR THE
EASTERN DISTRICT OF VIRGINIA
Alexandria Division

| | |
|---|---|
| GEOSCOPE TECHNOLOGIES PTE. LTD.,<br>Plaintiff,<br><br>v.<br><br>GOOGLE LLC,<br>Defendant. | No: 1:22-cv-01331-MSN-JFA |

**ORDER**

This matter comes before the Court on Defendant's Motion for Judgment on the Pleadings. (Dkt. No. 92). For the reasons set forth in the accompanying Memorandum Opinion, it is hereby

**ORDERED** that Defendant's Motion for Judgment on the Pleadings (Dkt. No. 92) is **GRANTED**; and it is further

**ORDERED** that the following Counts in the Complaint, which have not been resolved by the Court's Order on the parties' Stipulation of Partial Judgment of Noninfringement and Invalidity, are hereby **DISMISSED** pursuant to Rule 12(c) as patent ineligible under 35 U.S.C. § 101: Count I; Count II as it relates to claims 15 and 18 of U.S. Patent No. 8,400,358; Count III; and Count IV.

It is **SO ORDERED**.

The Clerk is directed to close this civil action.

/s/
Michael S. Nachmanoff
United States District Judge

Hon. Michael S. Nachmanoff
United States District Judge

Alexandria, Virginia
September 18, 2023

IN THE UNITED STATES DISTRICT COURT FOR THE
EASTERN DISTRICT OF VIRGINIA
Alexandria Division

| | |
|---|---|
| GEOSCOPE TECHNOLOGIES PTE. LTD.,<br>Plaintiff,<br><br>v.<br><br>APPLE INC.,<br>Defendant. | No: 1:22-cv-01373-MSN-JFA |

**ORDER**

This matter comes before the Court on Defendant's Motion for Judgment on the Pleadings. (Dkt. No. 82). For the reasons set forth in the accompanying Memorandum Opinion, it is hereby

**ORDERED** that Defendant's Motion for Judgment on the Pleadings (Dkt. No. 82) is **GRANTED**; and it is further

**ORDERED** that the following Counts in the Complaint, which have not been resolved by the Court's Order on the parties' Stipulation of Partial Judgment of Noninfringement and Invalidity, are hereby **DISMISSED** pursuant to Rule 12(c) as patent ineligible under 35 U.S.C. § 101: Count I; Count II as it relates to claims 15 and 18 of U.S. Patent No. 8,400,358; Count III; and Count IV.

It is **SO ORDERED**.

The Clerk is directed to close this civil action.

/s/
Michael S. Nachmanoff
United States District Judge

Hon. Michael S. Nachmanoff
United States District Judge

Alexandria, Virginia
September 18, 2023

**IN THE UNITED STATES DISTRICT COURT**
**FOR THE EASTERN DISTRICT OF VIRGINIA**

**Alexandria Division**

| | | |
|---|---|---|
| Geoscope Technologies Pte. Ltd | ) | |
| | ) | |
| Plaintiff, | ) | |
| | ) | |
| v. | ) | Civil Action No. 1:22-cv-01331 |
| | ) | |
| | ) | |
| Google LLC | ) | |
| | ) | |
| Defendant. | ) | |

**JUDGMENT**

Pursuant to the order of this Court entered on 09/18/2023 and in accordance with Federal Rules of Civil Procedure 58, JUDGMENT is hereby entered dismissing pursuant to Rule 12(c) as patent ineligible under 35 U.S.C. § 101: Count I; Count II as it relates to claims 15 and 18 of U.S. Patent No. 8,400,358; Count III; and Count IV.

FERNANDO GALINDO, CLERK OF COURT

By:_____/s/_____
J. Lanham
Deputy Clerk

Dated: 10/06/2023
Alexandria, Virginia

**IN THE UNITED STATES DISTRICT COURT**
**FOR THE EASTERN DISTRICT OF VIRGINIA**

**Alexandria Division**

| | | |
|---|---|---|
| Geoscope Technologies Pte. Ltd. | ) | |
| Petitioner | ) | |
| v. | ) | Civil Action No. 1:22-cv-01373-MSN-JFA |
| Apple Inc. | ) | |
| Respondent | ) | |

**JUDGMENT**

Pursuant to the Order of this Court entered on October 5, 2023 and in accordance with Federal Rules of Civil Procedure 58, JUDGMENT is hereby entered in favor of the Defendant Apple Inc. and against the Plaintiff Geoscope Technologies Pte. Ltd.

FERNANDO GALINDO, CLERK OF COURT

By: /s/
S. Williams
Deputy Clerk

Dated: 10/5/2023
Alexandria, Virginia

US007561104B2

(12) **United States Patent**
**Alles et al.**

(10) **Patent No.: US 7,561,104 B2**
(45) **Date of Patent: Jul. 14, 2009**

(54) **METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT**

(75) Inventors: **Martin Alles**, Vienna, VA (US); **John Carlson**, Dulles, VA (US); **George Maher**, Herndon, VA (US); **Selcuk Mazlum**, Leesburg, VA (US)

(73) Assignee: **Andrew LLC**, Hickory, NC (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/026,333**

(22) Filed: **Feb. 5, 2008**

(65) **Prior Publication Data**

US 2008/0186234 A1 Aug. 7, 2008

**Related U.S. Application Data**

(60) Provisional application No. 60/899,379, filed on Feb. 5, 2007.

(51) **Int. Cl.**
*G01S 3/02* (2006.01)

(52) **U.S. Cl.** ..... **342/451**; 342/457

(58) **Field of Classification Search** ..... 342/357.01, 342/357.06, 451, 457, 463–465; 455/456.6, 455/457

See application file for complete search history.

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| | | | |
|---|---|---|---|
| WO | 00/34799 | A1 | 6/2000 |

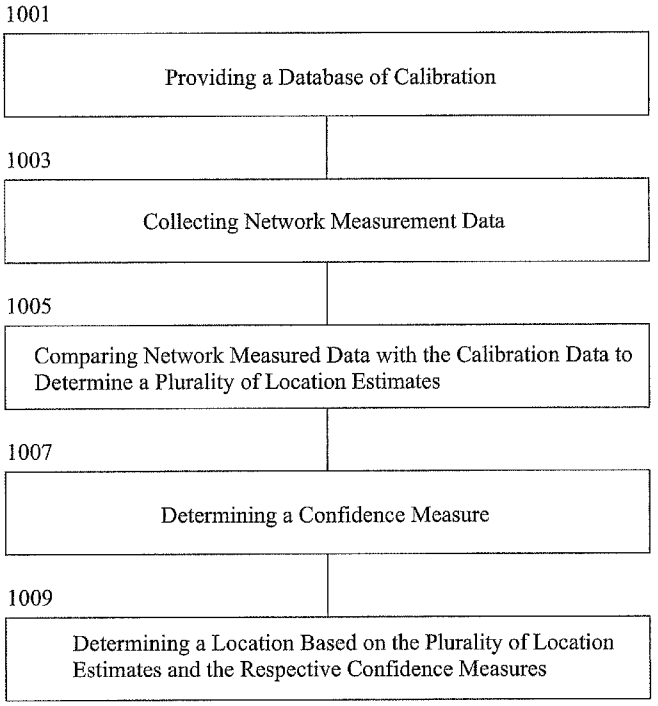
* cited by examiner

*Primary Examiner*—Dao L Phan
(74) *Attorney, Agent, or Firm*—Duane Morris LLP

(57) **ABSTRACT**

A method of modifying calibration data used to geo-locate a mobile station located in an indoor environment is disclosed. When a mobile station is located indoors, the signal strength of signals received and/or transmitted by the mobile station have the tendency to be lower than the strength of the signals received by a mobile station located outdoors. As a result of these lower signal strengths, geo-location efforts which rely on signal strengths may result in unsatisfactory location accuracy. Modifying pre-existing calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics.

**21 Claims, 10 Drawing Sheets**



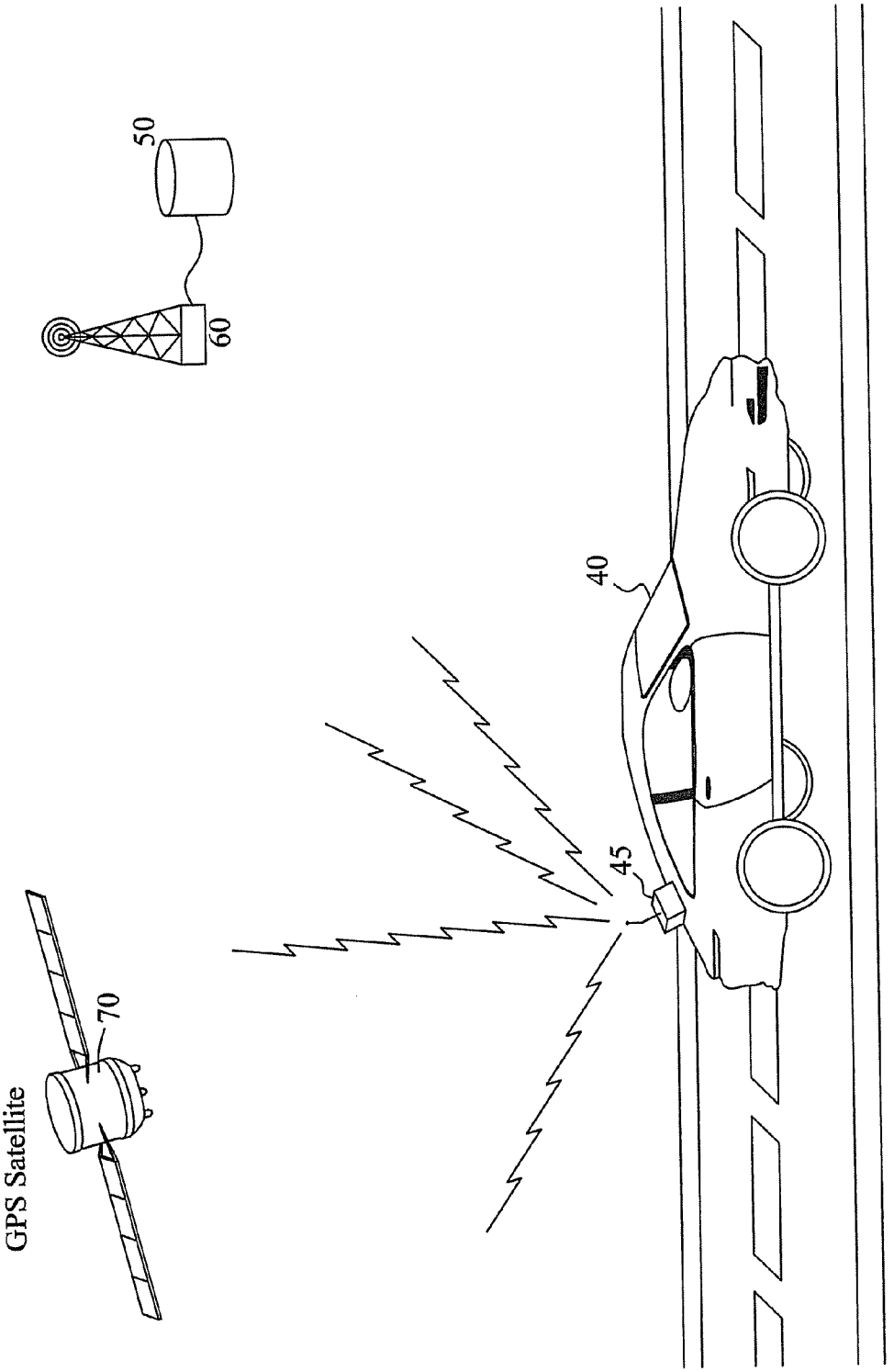



Figure 1

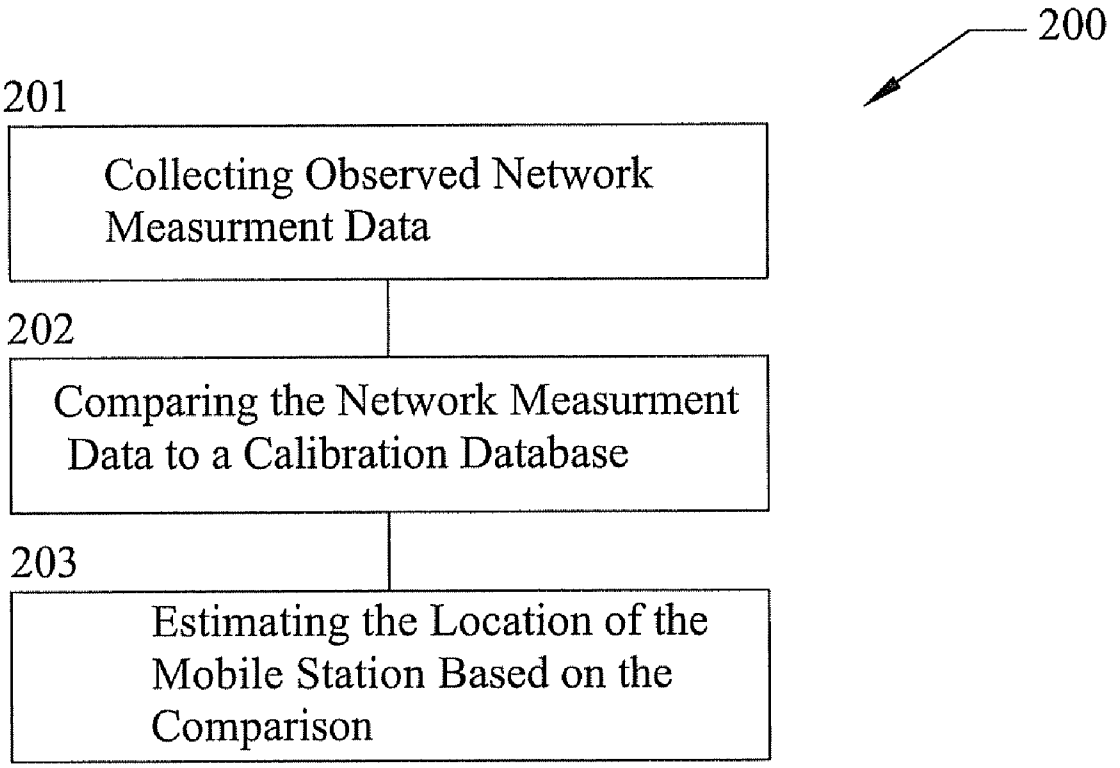

200
201
Collecting Observed Network Measurment Data
202
Comparing the Network Measurment Data to a Calibration Database
203
Estimating the Location of the Mobile Station Based on the Comparison

Figure 2

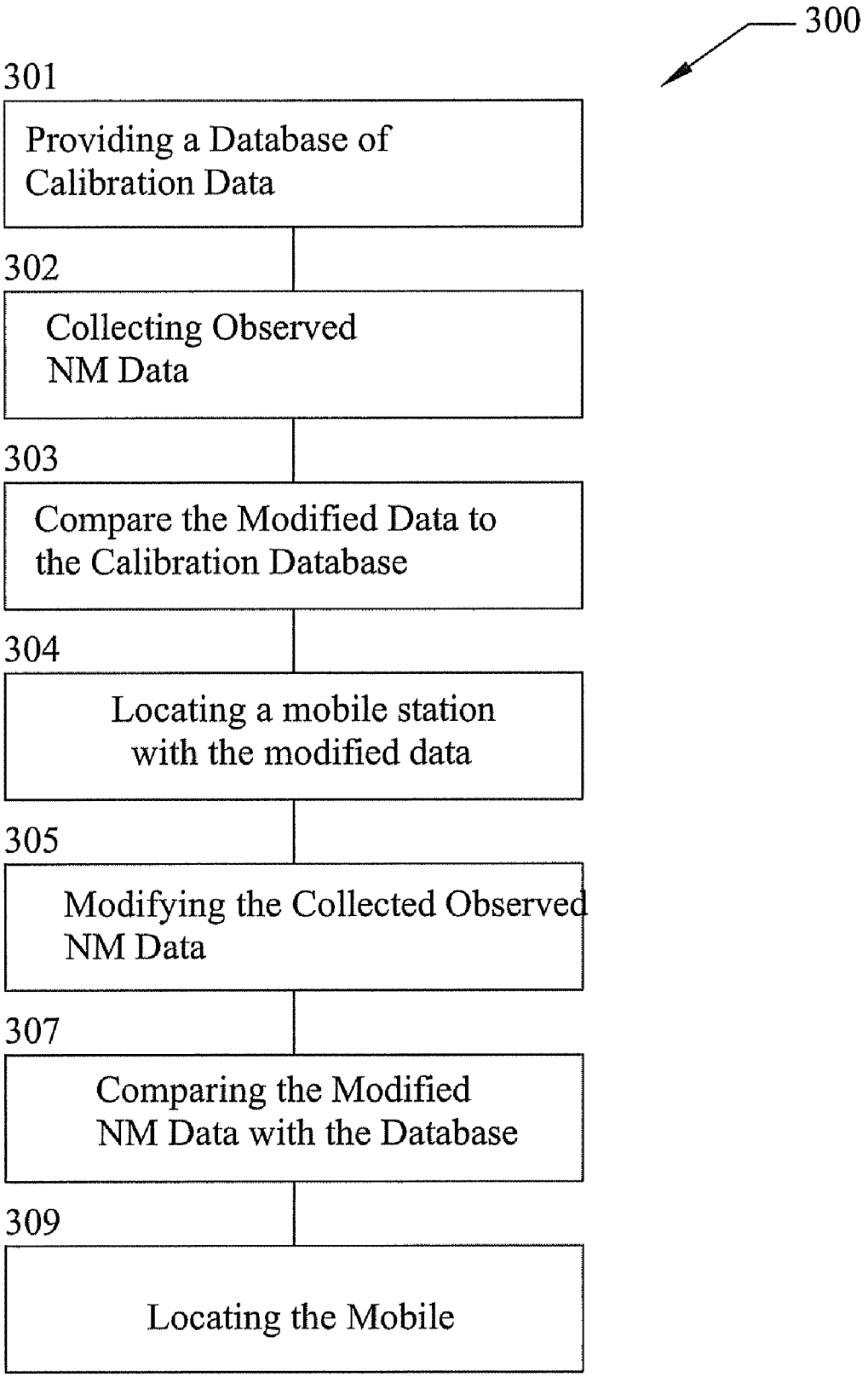

300
301
Providing a Database of Calibration Data
302
Collecting Observed NM Data
303
Compare the Modified Data to the Calibration Database
304
Locating a mobile station with the modified data
305
Modifying the Collected Observed NM Data
307
Comparing the Modified NM Data with the Database
309
Locating the Mobile

Figure 3

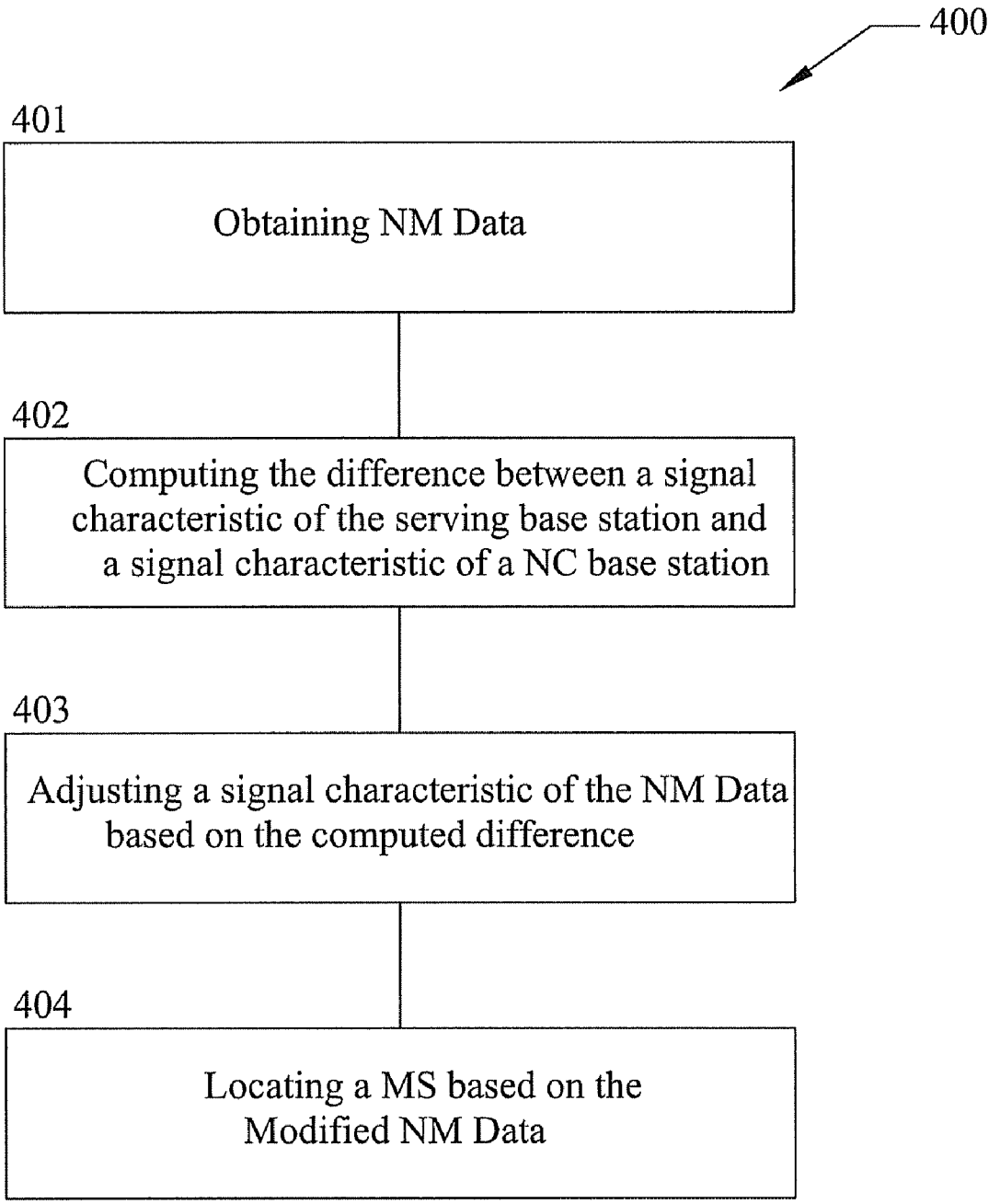

400
401
Obtaining NM Data
402
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station
403
Adjusting a signal characteristic of the NM Data based on the computed difference
404
Locating a MS based on the Modified NM Data

Figure 4

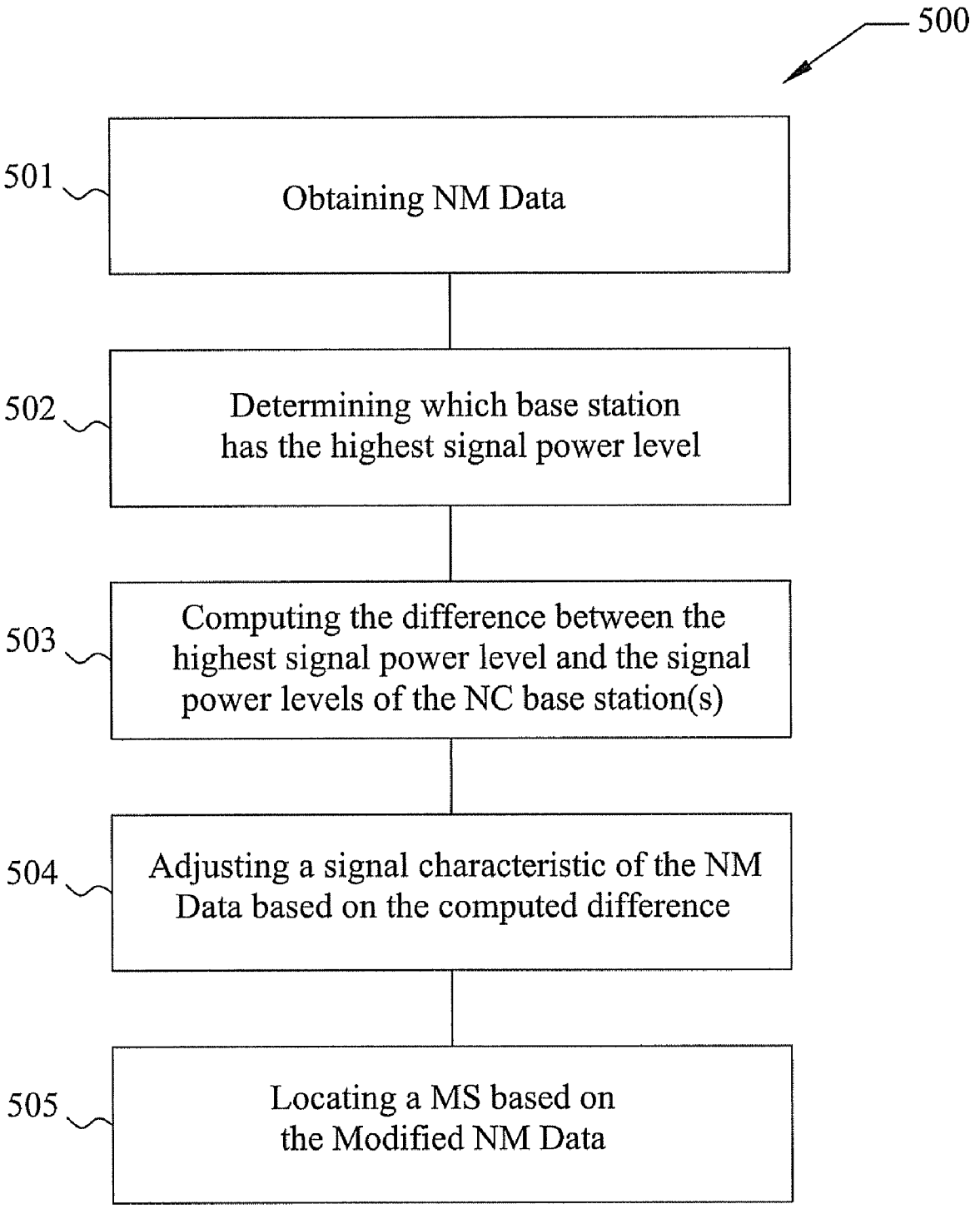

500
501
Obtaining NM Data
502
Determining which base station has the highest signal power level
503
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
504
Adjusting a signal characteristic of the NM Data based on the computed difference
505
Locating a MS based on the Modified NM Data

Figure 5

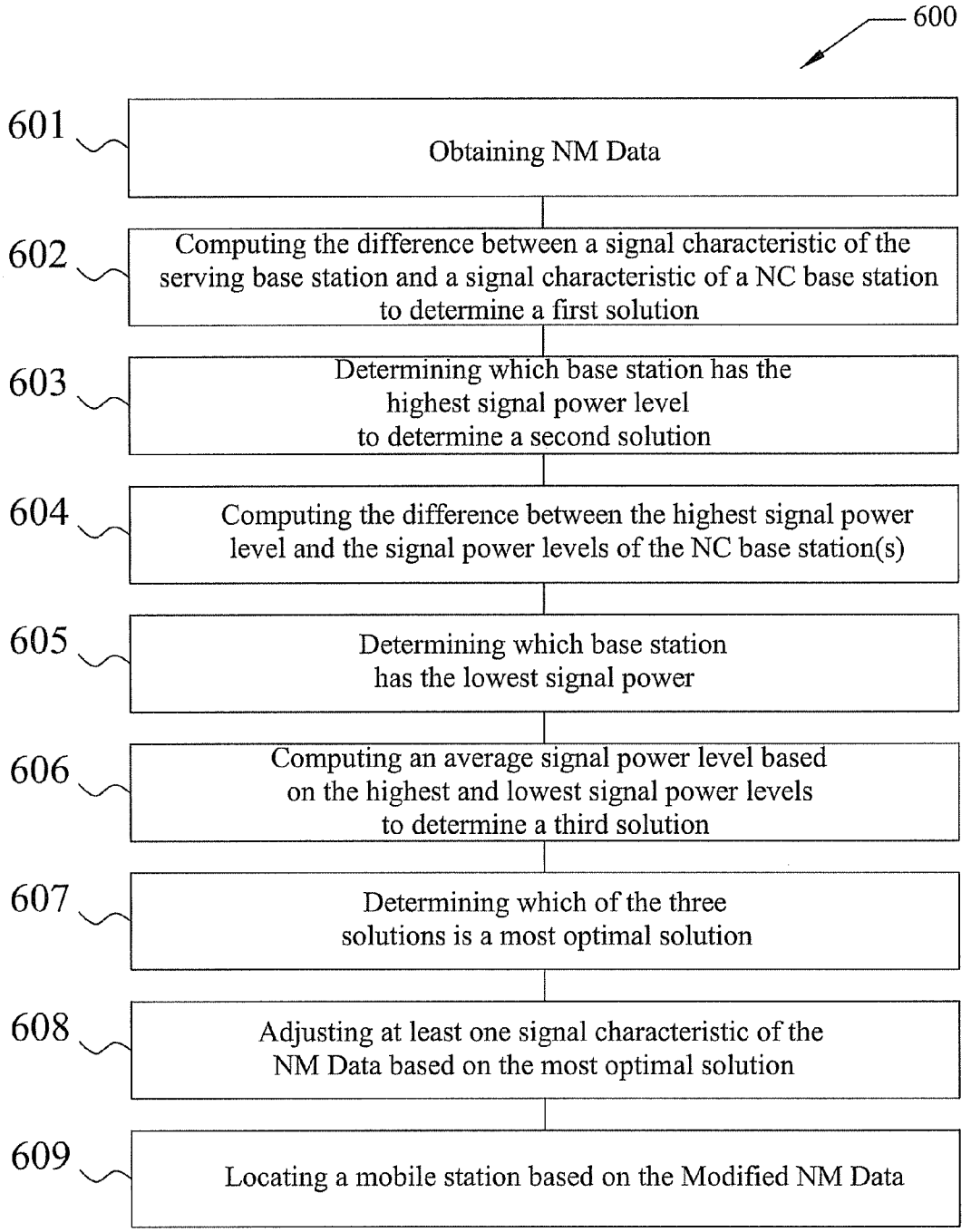

600
601
Obtaining NM Data
602
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station to determine a first solution
603
Determining which base station has the highest signal power level to determine a second solution
604
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
605
Determining which base station has the lowest signal power
606
Computing an average signal power level based on the highest and lowest signal power levels to determine a third solution
607
Determining which of the three solutions is a most optimal solution
608
Adjusting at least one signal characteristic of the NM Data based on the most optimal solution
609
Locating a mobile station based on the Modified NM Data

Figure 6

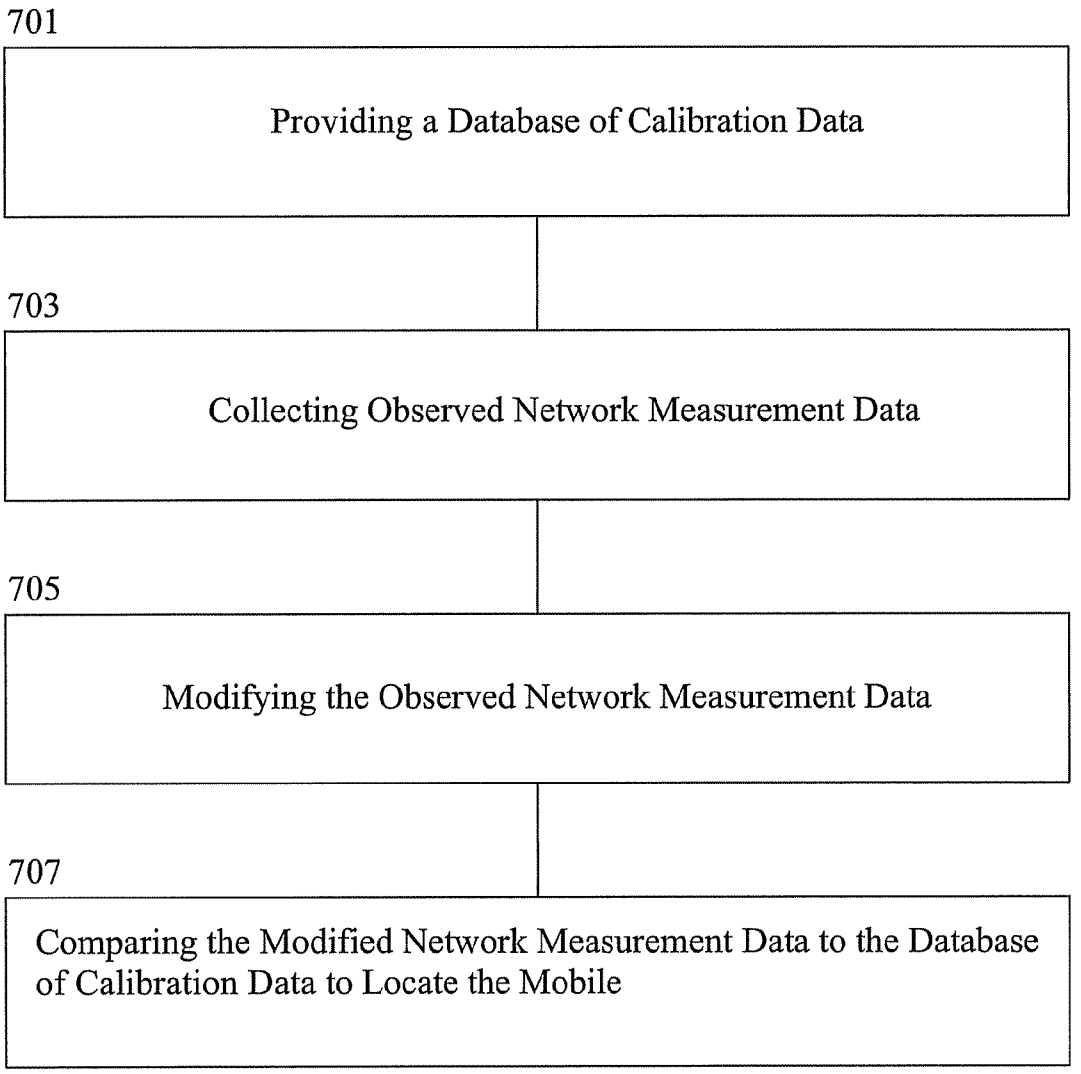

701
Providing a Database of Calibration Data
703
Collecting Observed Network Measurement Data
705
Modifying the Observed Network Measurement Data
707
Comparing the Modified Network Measurement Data to the Database of Calibration Data to Locate the Mobile

Figure 7

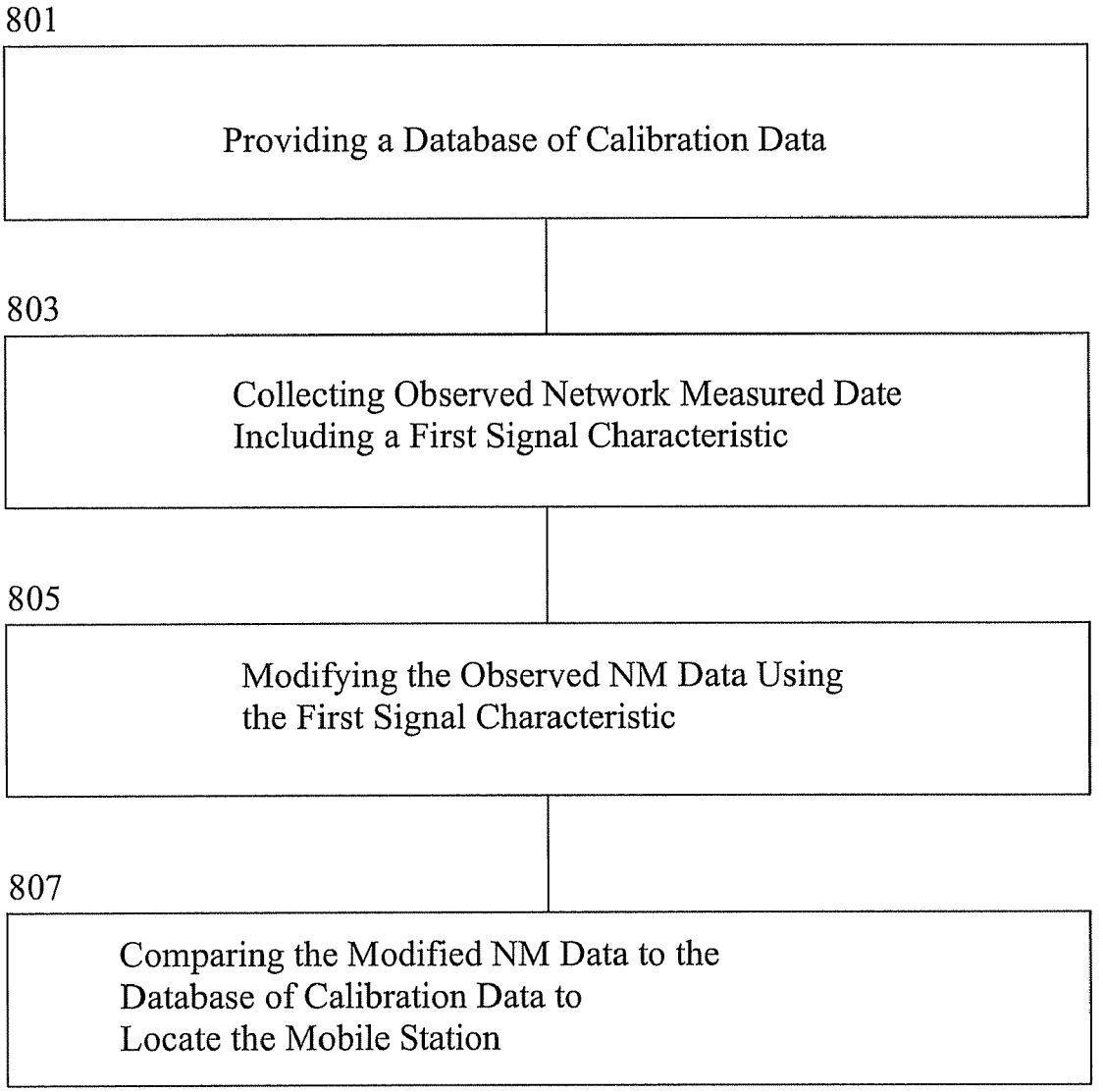

801
Providing a Database of Calibration Data
803
Collecting Observed Network Measured Date Including a First Signal Characteristic
805
Modifying the Observed NM Data Using the First Signal Characteristic
807
Comparing the Modified NM Data to the Database of Calibration Data to Locate the Mobile Station

Figure 8

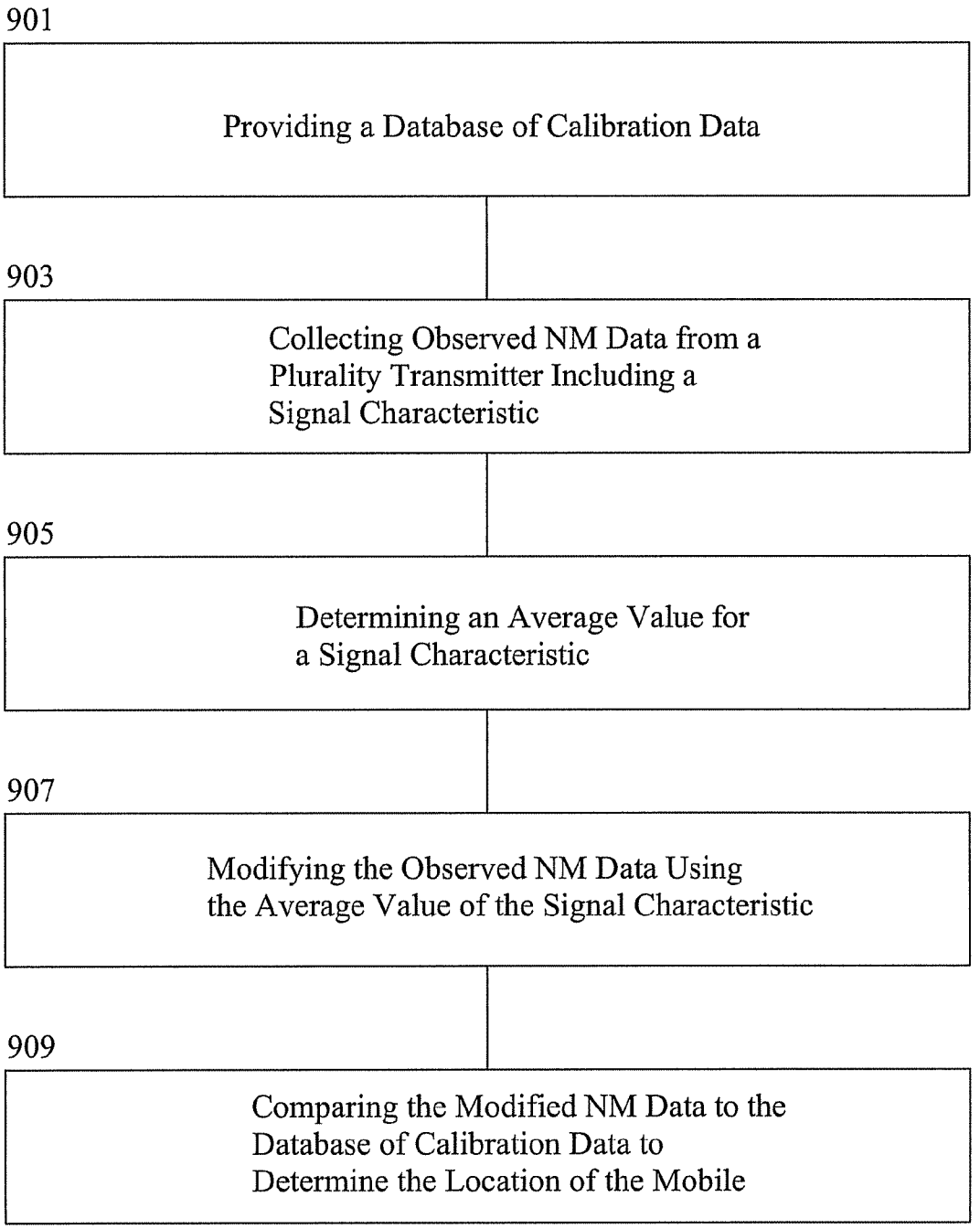

901
Providing a Database of Calibration Data
903
Collecting Observed NM Data from a Plurality Transmitter Including a Signal Characteristic
905
Determining an Average Value for a Signal Characteristic
907
Modifying the Observed NM Data Using the Average Value of the Signal Characteristic
909
Comparing the Modified NM Data to the Database of Calibration Data to Determine the Location of the Mobile

Figure 9

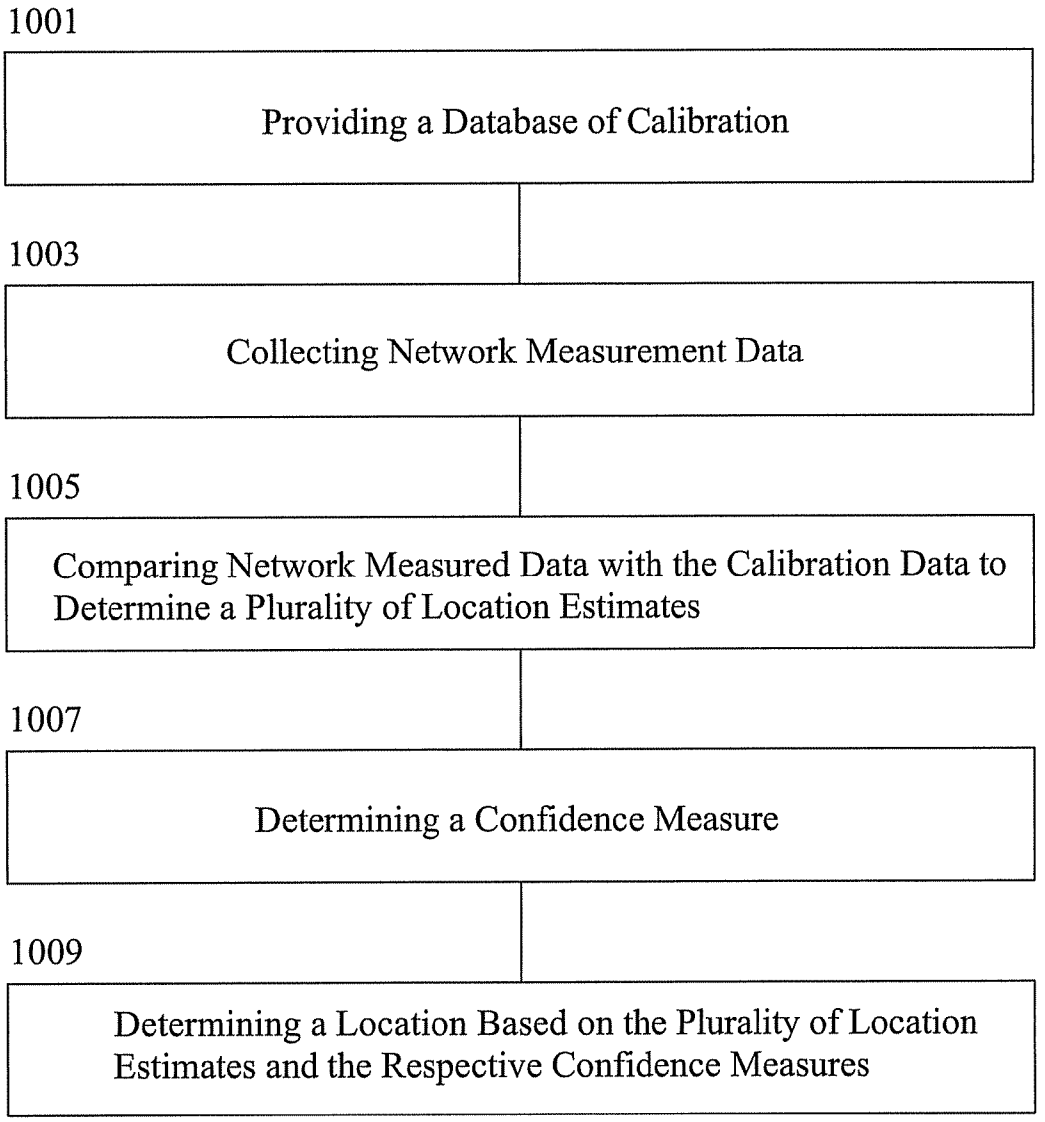

1001
Providing a Database of Calibration
1003
Collecting Network Measurement Data
1005
Comparing Network Measured Data with the Calibration Data to Determine a Plurality of Location Estimates
1007
Determining a Confidence Measure
1009
Determining a Location Based on the Plurality of Location Estimates and the Respective Confidence Measures

Figure 10

# METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT

## CROSS REFERENCES

The present application is related to provisional application No. 60/899,379 entitled "Mobile Location Using Network Measurement Reports" filed on Feb. 5, 2007, which is hereby incorporated by reference in its entirety.

## BACKGROUND

The use of wireless communication devices such as telephones, pagers, personal digital assistants, laptop computers, etc., hereinafter referred to collectively as "mobile appliances" or "mobiles stations" has become prevalent in today's society. In recent years, at the urging of public safety groups, there has been increased interest in technology which can determine the geographic position or "geo-locate" a mobile station in certain circumstances.

Estimating the location or "geo-locating" a mobile station may require one or more types of calibration data associated with the mobile station (e.g., signal strength, round trip time, time difference of arrival (TDOA), etc.). Calibration data is typically collected in an outdoor environment. The primary reason for collecting calibration data outdoors is the greater ease of performing automated calibration collection procedures or, in some instances, manual collection procedures along roads. It is more time-consuming to perform calibration procedures indoors due to the required access to buildings and the inability to utilize automated collection procedures designed for outdoor environments.

When a wireless device is located indoors, the signal strengths of signals received from the serving and/or neighboring base stations tend to be lower than the strength of the signals received by a wireless device located outdoors. As a result of these lower signal strengths, performing comparisons between the received signal strengths of the indoor wireless device and signal strength data stored in a calibration database may result in a poor estimated location accuracy. Modifying the calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics. Calibration data collected in areas located adjacent to indoor facilities may be altered to increase the accuracy of location estimates of a mobile station located indoors.

One embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network and collecting observed network measurement data. The method also includes modifying the observed network measurements and then comparing the modified data with the database of calibration data to determine the location of the mobile station.

Another embodiment of the present subject matter is a system for determining a location of a mobile station. The system includes a database of previously-gathered calibration data for a region in a wireless network and circuitry such as a wireless receiver for collecting observed network measurement data. The system includes circuitry, such as a processor, for modifying the observed network measurement data; and circuitry, such as a processor, for comparing the modified data with the calibration data in the database to determine the location of the mobile station.

Yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered



calibration data for a region in a wireless network which includes a serving transmitter. The method collects observed network measurement data including a first network characteristic from said serving transmitter and modifies the observed network measurement data using said first characteristic. The method compares the modified network measurement data with the database of calibration data to thereby determine the location of the mobile station.

Still yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network including a first transmitter and a second transmitter. The method also includes collecting observed network measurement data including a first and second signal characteristic from the first and second transmitters respectively and determining which of the first and second signal characteristics has a greater magnitude. The observed network measurement data may be modified using the greater magnitude signal characteristic, and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station.

A further embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network and collecting observed network measurement data from a plurality of transmitters which includes a signal characteristic from each one of said plural transmitters. The method also includes determining an average value for the signal characteristics and modifying the observed network measurement data using the average value. The method may then compare the modified network measurement data with the database of calibration data to determine the location of the mobile station.

Still a further embodiment of the present subject matter recognizes that it may be desirable to locate a mobile station by obtaining at least one network measurement report representing at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of neighboring base stations. The method may also compute the difference between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the neighboring base stations to determine a first solution and determine which neighboring base station has the highest signal power level at a particular location. The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be computed to determine a second solution. It may also be determined which neighboring base station has the lowest signal power level at the particular location. The method may also comprise computing an average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level to determine a third solution and determining which of the three solutions is a most optimal solution based on at least one comparison of the three solutions. At least one signal characteristic of the network measurement report may be adjusted based on the most optimal solution and the modified network measurement report may be utilized to locate a mobile station.

Another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered outdoor calibration data for a region in a wireless network, collecting network measurement data, and comparing the network measurement data with the database of calibration

data to thereby determine several location estimates of the mobile station. The method may also include determining a confidence measure for each of the plurality of location estimates and determining the location of the mobile station based on the plurality of location estimates and their respective confidence measures.

These and other advantages of the disclosed subject matter over the prior art will be readily apparent to one skilled in the art to which the disclosure pertains from a perusal of the claims, the appended drawings, and the following detailed description of the preferred embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless communications networking environment.

FIG. **2** illustrates a flow diagram of an exemplary inventive concept.

FIG. **3** illustrates a flow diagram of another exemplary inventive concept.

FIG. **4** illustrates a flow diagram of yet another exemplary inventive concept.

FIG. **5** illustrates a flow diagram of still another exemplary inventive concept.

FIG. **6** illustrates a flow diagram of still yet another exemplary inventive concept.

FIG. **7** illustrates a flow diagram of an embodiment of the subject matter.

FIG. **8** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **9** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **10** illustrates a flow diagram of another embodiment of the subject matter.

## DETAILED DESCRIPTION

Calibration data samples obtained outdoors may be used to simulate indoor calibration data to locate a mobile station (MS) in an indoor facility. A method of utilizing calibration data samples to represent indoor and/or outdoor wireless networking environments is described herein.

Reliably locating a mobile station located indoors, even when the calibration data has been obtained in an outdoor environment, may simplify a calibration collection procedure. Calibration data obtained outdoors may be modified and substituted for indoor calibration data. In addition network measurement data may be modified for comparison with the outdoor calibration data.

In general, a non-uniform grid point (NUG) may represent the signal characteristics and/or calibration data over a given region. As illustrated in FIG. **1**, a set of NUGs (NUG**1**, NUG**2** and NUG**3**) are shown as being a part of a larger geographical region (R), which includes various wireless networking components (e.g., (MS **11** and BS **20**—NUG**1**), (MSs **12-15**—NUG**2**) and (MSs **16-18** and BS **30**—NUG**3**)). The NUGs represent an area of collected calibration data, which may be stored in a database for easy retrieval during a calibration data comparison operation between the NUG and a received network measurement report (NMR).

Calibration data may be obtained from data collection devices during field test operations, and/or from MSs or other communication devices within the general area of the NUG. Cross-NUG communications may occur between MSs and/or BSs located within communication range of one or more of the NUGs. For example, BS **10** may be located outside the region (R) and may communicate with one or more devices located in the various NUGs **1-3**. The different NUGs **1-3** may be separately defined by a variety of parameters. For example, geographical areas (e.g., mountains, buildings, roads) may be a factor in deciding the boundaries of a NUG. Additionally, varying concentrations of MSs may be another factor that separates one NUG from another.

Network measurement reports (NMRs) may be used to represent network characteristics at particular locations within a given region (R). Any point located within a NUG may have corresponding signal strength levels that represent the signal power of the serving and/or neighboring cell (NC) BSs. An exemplary NMR may be represented by example_data_vector=[P**1**, P**2**, P**3**, TA**1**]. Referring to FIG. **1**, the power level signals (P**1**-P**3**) may represent the power levels of the three BSs **10**, **20** and **30**, as measured at a particular location. The timing advance parameter TA**1** (or equivalent parameter) may be used to represent timing information of signals transmitted between the MS and one or more BSs.

The value of the timing advance (TA) parameter corresponds to the length of time a signal from a MS takes to reach a particular BS. A MS may be configured to transmit data signals at specific timeslot intervals depending on the type of wireless communication protocol employed (e.g., TDMA, GSM, 3GPP etc.). Using the speed of light (c=3*10^8 m/s) as a reference velocity for the radio waves, the TA parameter may be increased or decreased depending on the distance between the MS and the BS. The TA parameter may be periodically adjusted as the distance from the MS to the BS changes. Of course, a NMR may contain any number and type of parameters, and may be used to estimate the location of a MS.

For example, NMR(s) may be transmitted from the MS or from other wireless communication components to position determining equipment (PDE) **50**, which processes the received NMR information and may attempt to locate the position of the MS. NMR(s) may be periodically generated by MSs or other communication devices to calibrate the NUG. The NUG may also be based entirely on information received from NMR(s) generated by MSs located in the NUG.

The received Network Measurement data (NM data) may be compared to predetermined calibration data representing one or more NUGs to estimate the location of a MS. In a case where NM data is compared against a NUG, like parameters may be compared to estimate if the target MS **18** is within the NUG. Similarly, NUG parameters may be computed in response to a comparison operation, and then compared to the NM data. Each NUG may have a series of parameters and/or functions characterizing one or more particular locations in the NUG. Given a received set of one or more NMR(s) obtained from some unknown location, an estimate of that unknown location may be calculated using the characterization of the NUG or uniform grid (UG) over that region.

It may be desirable to use the original unmodified NM data directly without modification when locating a mobile station. Assuming the MS is located in an indoor facility, the data contained in the NMR(s) may be a function of calibration data collected outdoors. In some cases, the unmodified outdoor calibration data used to represent the indoor facility may provide an accurate representation of the location of the target MS **18** (e.g., low distortion structures, open-faced facilities, etc.).

Referring to FIG. **1**, the NM data may be sent from the target MS **18** to the BS **10**, where the PDE **50** processes the NMR and performs one or more comparison operations between the NM data and the calibration data of the NUG(s). Once the comparison operation is complete, the location of the target MS **18** may be estimated. A direct comparison of the

original NM data may be made against the corresponding NUG(s) characteristics. Alternatively, the NM data may not be modified even if NUG(s) are utilized to estimate the location of the mobile station.

NM data may also be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations. For example, differences in parameters between the serving cell and the NC may be calculated and the quantities used to modify the original NM data.

If an original NMR received at the PDE **50** had the form NMR**1**=[P**1**, P**2**, P**3**, TA**1**], where P**1** is the serving BS power at a particular location, P**2** is a first NC power, P**3** is a second NC power, and TA**1** is the timing advance parameter, the modified NMR may be represented by: NMR_modified=[0, P**1**-P**2**, P**1**-P**3**, TA**1**]. The resulting data vector may be used to calculate new relative power levels of the NC BSs by subtracting or adding the NMR_modified parameters from the original NMR**1** parameters. In this example, the power of the serving BS may be used as a basis to obtain relative power level modification parameters to modify the NC power level parameters of NMR(s).

The calculated modified parameters (NMR_modified=[0, P**1**-P**2**, P**1**-P**3**, TA**1**]) may also be used to simulate an indoor facility by modifying NMR(s) received from an indoor location. Alternatively, the modified parameters may be used to conduct other calculations to obtain a desired set of modified results. For example, the modified NMR may be compared to one or more of the NUG(s) to provide an estimated location of a MS. Of course, the serving BS power level is not a required parameter to be used as a basis to obtain relative power level modification parameters, and many other parameters may be used to modify the NM data to simulate an indoor facility.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevServing_WD represents the received signal strength of the serving base station's control channel measured by the wireless device at an unknown location. Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel, RxLevServing_DB represent the average received signal strength of the serving station's control channel, stored in a database of the PDE **50** during the calibration process, and RxLevNeigh_i_DB represent the average received signal strength of the $i^{th}$ neighbor's control channel stored in the database during a calibration process (i=1 to N, where N is the number of neighbor cells reported).

A comparison operation may be conducted between the received signal strengths of the NC-BSs relative to the serving BS's received signal strength. For example, a comparison may include computing the difference between the parameters of the serving base station and the $i^{th}$ neighbor's parameters (i.e., (RxLevServing_WD−RxLevNeigh_i_WD) and (RxLevServing_DB−RxLevNeigh_i_DB)). Once the differences are calculated, the magnitudes of the differences may be compared to a predetermined threshold value used to distinguish between an acceptable difference value requiring no modification to the NM data and a non-acceptable difference value invoking further modification efforts.

NM data may be modified by an amount relative to the signal strength of a NC-BS. In this example, the NC-BS having the highest signal power may be used as a basis to modify the values of the NM data. The differences between the NC having the highest cell power and the cell powers of the remaining NC-BSs may be calculated and the quantities thereof used to modify the original NM data.

An exemplary NMR may have the form NMR=[P**1**, P**2**, P**3**, P**4**, TA**1**], where P**1** is the serving BS signal power, P**2** is a NC having the highest signal power at the intended location of the NMR, P**3** and P**4** are different NC signal powers, and TA**1** is a timing advance parameter. In this example, P**2** has the highest signal power level and may be used as the basis for modifying the parameters of the NMR. The modified NMR may then be represented by NMR_modified**2**=[P**2**-P**1**, 0, P**2**-P**3**, P**2**-P**4**, TA**1**]. The resulting data vector NMR_modified**2** may be used to calculate new power levels of the NC base stations by subtracting or adding the NMR_modified**2** parameters to the original NMR parameters.

The modified NMR may be compared to one or more of the NUG(s). In the previous examples, the power of the serving BS and the NC with the highest signal power level were used to obtain the relative power modification quantities. The signal power level of the serving BS and/or the NC having the highest signal power may be used solely to modify the NMR, and may not be included in comparison operations against the NUG(s). If the serving BS power level parameter and/or the NC having the highest signal power level parameter are excluded from the comparison to the NUG(s), the first and/or additional terms of the NMR may be ignored during the comparison operation. Of course, any other parameter may be utilized and the example above including power level should not limit the scope of the claims appended herewith.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevNeigh_h_WD represents the received signal strength of a neighboring BS's control channel (neighbor A) having the highest signal level, as measured by the wireless device. RxLevNeigh_h_WD may be listed first in a measurement report list containing signal strengths sorted in descending order (h=1). Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel measured (neighbor i, where i≠h), as by the wireless device, and RxLevNeigh_h_DB represent the received signal strength of the neighbor (neighbor A) with the highest received signal strength, as measured by the wireless device, and which may be stored in the PDE **50** database during a calibration process. RxLevNeigh_i_DB may be used to represent the received signal strength of the $i^{th}$ neighboring BS's control channel (neighbor i, where i≠h, and i=1 to N, and where N is the number of neighbors reported). RxLevNeigh_i_DB may be stored in the PDE **50** database during a calibration process.

In this example, correlation may be conducted over the received signal strengths of the NC-BSs relative to the NC-BS having the highest received signal strength, as observed by the wireless device. A comparison may include computing the difference between the parameters of the serving BS and the $i^{th}$ neighbor's parameters (i.e. (RxLevNeigh_h_WD−RxLevNeigh_i_WD) and (RxLevNeigh_h_DB−RxLevNeigh_i_DB)). Comparisons may also be conducted for any one, combination of or all of the measured parameters of the NC-BSs.

NM data may be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations by an amount relative to the average signal strength of one or more NC base stations. Each signal power or parameter component of the NMR may also be modified by an average signal power or parameter level based on one or more of the measured NC signal power levels. The average received signal power level may be calculated a number of different ways, for example, the average of the two highest signal powers, the three highest powers, the average of all (N) signal powers, or an intermediary number between one or more of the measured NC signal power components. Modifying the original NMR components may include subtracting or adding to the existing NMR power components by an amount based on the calculated average, or other various known functions.

To further illustrate modification of the NMR, consider a particular implementation where RxLevNeigh_avg_WD represents the average received signal strength based upon a number of control channel signal powers of neighboring BSs, as measured by the wireless device at an unknown location to be estimated. Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel signal power, and RxLevNeigh_avg_DB represent the average received signal strength of data stored during calibration, and computed based on the neighboring BSs, as measured by the wireless device and used in computing the average received signal strength. The same neighboring BSs may be used to represent the average received signal strength of the signal power levels received by the wireless device and for the average received signal strength of calibration data stored in the PDE **50** database. Let RxLevNeigh_i_DB represent the received signal strength of the $i^{th}$ neighbor's control channel stored in the PDE **50** database during the calibration process (i=1 to N, where N is the number of neighbors reported).

In this example, a comparison may be conducted over the received signal strengths of the neighboring BSs relative to the average received signal strength computed for all neighboring BSs observed by the wireless device (i.e., compare between (RxLevNeigh_avg_WD−RxLevNeigh_i_WD)) and for all neighbors previously measured by the wireless device (i.e., compare between (RxLevNeigh_avg_DB−RxLevNeigh_i_DB)). The average signal power level observed over all the neighbor signal power levels may be realized in absolute powers (mW) or in relative powers (dBm).

Any combination of the above NMR modification procedures may be performed to increase the accuracy of mobile station location estimates. Further, any number of or type of parameters may be utilized in any of the aforementioned procedures and the exemplary parameters of power level, signal strength, etc. should not limit the scope of the claims appended wherewith. Certain factors impacting the modification procedure selection process may include the specific type of cellular technology, the geographical terrain and/or environmental conditions, etc. Further, the present subject matter acknowledges that some NMR modification procedures may be best suited for outdoor location estimation, while others are better suited for indoor location estimation, and some even may be best for mixed (indoor & outdoor) location estimation.

For example, if the serving BS for a mobile station is known to be in an area where there are no buildings or obstructions then it may be prudent to leave the NM data unmodified or select the NMR modification procedure where the serving base station is used as the basis to calculate NMR modifications. Further, if the serving cell is in a geographical area with known large obstructions (e.g., buildings, mountains etc.) then it may be prudent to use the NMR modification procedure that selects the NC base station having the highest signal power as the basis to calculate NMR modifications. Additionally, if the serving cell is in an area containing both outdoor and indoor facilities, then it may be best to use the average of more than one NC signal power value as the basis to modify the NMR(s).

Regardless of the type of modification algorithm selected to modify the NM data, a margin of error may still be present when attempting to determine the precise location of a mobile station. Determining the amount of location error may be useful when estimating the likelihood of accurately locating a mobile station. A confidence measure may also be used to represent the accuracy of a mobile station's estimated location.

The value of a confidence measure may vary depending on the estimated accuracy of the location estimated. If estimated locations derived from mapping NM data to a given location, whether using a NUG or other form of a data source for comparison purposes, agree under any or all combinations, the respective confidence measure "C" may be considered high. A confidence measure may also be represented as a function that increases as the quantity of measured data correctly matches data associated with a final estimated location. An exemplary confidence measure or function may be represented as a fraction of all locations that are similar to the final estimated location, however, such an example should not limit the scope of the claims appended herewith.

After one or more of the data modification procedures have been calculated, respective confidence measures may be calculated to represent the likely accuracy of the modification procedures. Confidence measures may then be compared and the best one selected to represent the appropriate modification procedure to implement.

Certain estimated locations may be assigned weights by using a confidence measure as a weight to represent the probability of locating a mobile station at a given location. For example, confidence measures may be based on one or more calculated parameters, including, but not limited to: a probability density function (PDF), a joint PDF, Mahalanobis distance, distortion measure, ordered number parameter, timing advance (TA) parameter, mobile orientation etc. The calculated parameters may be derived from the NUG calibration data stored in the PDE **50** database. The parameters may be pre-stored in memory or may be calculated during a NMR to NUG comparison operation.

Probability density functions may be calculated based on an individual NC base station power level, or a set of multiple NC base station power levels. The calculated probability density function may be compared to the set of available NUGs (i.e., NUGS **1-3** of FIG. **1**) to determine a probability that the NM data matches a particular NUG location. A joint probability may also be calculated over a set of probabilities to further estimate the location of the mobile station. The results of the calculated PDF may be used in a number of estimation techniques to locate the mobile station.

Distortion measures may be determined at a particular location may be included in a NMR and used in a comparison operation to measure the difference in distortion between NUG data and NM data. The distortion measures may be used to estimate a location of a mobile station based on the results of the comparison.

A Mahalanobis distance may be an exemplary distortion measure and may utilized to assist in identifying and analyzing different patterns in a wireless communications environment. The Mahalanobis distance may also be useful in determining similarities between an unknown sample data set and a known data set.

Ordering number lists may also be used to organize parameters for comparison purposes. An ordering number list may be a list or table of data parameters organized in a particular order. The power levels may be listed in descending order and compared to similar parameters associated with a NUG(s). A threshold power level may be used to represent an acceptable amount of deviation between a comparison of power levels obtained from a NMR(s) and/or a NUG(s). If one or more power levels in the NMR(s) and the NUG(s) fall within an acceptable range of one another, the location of a mobile station may be measured with a corresponding degree of accuracy.

Each generated NMR may be used to provide an individual estimate of the mobile station's location. The PDE **50** may

receive a number of NMRs over a period of time, a corresponding number of location estimates may be generated based on the number of NMRs received. These estimates may be combined in a statistical algorithm and may provide a more accurate location estimate than the individual NMRs.

Given a particular NMR or set of NMR(s) containing data collected outdoors, a selection procedure may be conducted to select the most appropriate modification procedure to use when modifying the NM data. Once one or more of the above described NMR modification procedures have been calculated, (e.g., non-modification, serving cell power level, highest NC power level, average(s) of the NC power levels, etc.) one or more of these calculations may be selected as an optimal solution to be used to modify the NMR.

One way to determine the optimal solution that should be used to modify the NMR is to calculate a confidence measure for each of the calculated modification procedures. Once the confidence measures have been calculated, the optimal solution may be selected as the modification procedure with the highest confidence measure. Alternatively, a location estimate may be made by weighting the individual solutions by the applicable confidence measure and combining the results into a single NMR solution.

Combining multiple NMR(s) may generate a location estimate with increased accuracy. When comparing NM data to a NUG, the grid point data that most closely matches the NM data may become the estimated location of the mobile station. In an alternative arrangement, interpolation may be used for determining a location that falls between two grid points to provide an even more accurate location estimate. Applying probabilistic weights, hypotheses and deriving confidence measures may increase the accuracy of the location estimates. Utilizing exemplary probabilistic measures, the estimated location of a mobile station may be determined within a particular degree of certainty. A similar approach may also be applied to select the appropriate NMR modification procedure to accommodate for varying conditions and other operational variables (e.g., different air standards, varying environmental circumstances, etc.).

FIG. **2** illustrates a flow diagram **200** of a method to locate a mobile station. Observed network measurement data may be collected (operation **201**). The observed data would typically be the same or similar to the data in a network measurement report (NMR). The network measurement data represents at least one network characteristic observed by the mobile station operating at a particular location within a region. The NM data may be compared to calibration database data, where the calibration database data represents calibration data measured within the geographical area of the region (operation **202**). The location of the mobile station may be estimated based on the comparison of the modified network measurement data and the calibration database data (operation **203**).

FIG. **3** illustrates a flow diagram **300** of a method to locate a mobile station in an indoor environment. Calibration data samples are collected in an outdoor environment (operation **301**). At least one attenuation variable may be applied to the calibration data sample to simulate an indoor environment (operation **302**). The modified network measurement data sample may be applied to a mobile station location algorithm (operation **303**). The mobile station may be then located in the indoor environment based on the mobile station location algorithm implementing the at least one modified calibration sample (operation **304**).

FIG. **4** illustrates a flow diagram **400** of a method to locate a mobile station. NM data may be obtained to represent at least one network characteristic of the mobile station's serving base station and at least one second network characteristic of at least one of the mobile station's neighboring base stations (operation **401**). The difference between the at least one first signal characteristic and the at least one second signal characteristic may be computed (operation **402**). At least one signal characteristic of the NM data may be adjusted based on the computed difference (operation **403**). The mobile station may be then located based on the modified network measurement data (operation **404**).

FIG. **5** illustrates a flow diagram **500** of a method to locate a mobile station. NM data may be obtained (operation **501**), which represents at least one first network characteristic of the mobile station's serving base station, and at least one second and third network characteristic of the mobile station's at least two neighboring base stations. It may be then determined which base station has the highest signal power at a particular location (operation **502**). The difference between the highest signal power at the particular location and the power levels at the particular location of the serving base station and the remaining neighboring base stations may be determined (operation **503**). At least one signal characteristic of the NM data may be adjusted based on the computed differences (operation **504**). The mobile station may then be located based on the modified NMR (operation **505**).

FIG. **6** illustrates a flow diagram **600** of a method to locate a mobile station. A NMR may be obtained (operation **601**), which represents at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of the mobile station's at least two respective neighboring base stations. A difference may be computed between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the mobile station's neighboring base stations to determine a first solution (operation **602**). It may then be determined which base station has the highest signal power level at a particular location (operation **603**). The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be determined as a second solution (operation **604**). The neighboring base station having the lowest signal power level at the particular location may be determined (operation **605**). An average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level may be determined as a third solution (operation **606**). It may then be determined which solution is a most optimal solution by comparing the three solutions (operation **607**). The signal characteristic of the NM data may then be adjusted based on the most optimal solution (operation **608**). The mobile station may then be located based on the adjusted NM data (operation **609**).

FIG. **7** illustrates an embodiment of the present subject matter. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network (operation **701**). The database may be a collection of data from uniform or non-uniform grids that contain network measurements with associated location estimates. Network measurement data may be then observed and measured typically by a mobile station or any other wireless device (operation **703**). The network measurement data may include received base station power and timing advance, as well as other network characteristics observable by a mobile station. The observed network measurement data may then be modified (operation **705**). This modification may include applying an attenuation function to some or all of the network measurement data or converting absolute values into relative values. The modification may be performed by a processor,

microprocessor or ASICS. The modified network measurement data may then be compared to the calibration database in order to determine the location of the mobile station (operation **707**). The comparison may be performed by a processor, microprocessor or ASICS.

FIG. **8** is another illustration of an embodiment of the present subject matter. A database of previously-gathered calibration data for a predetermined region in a wireless network may be provided (operation **801**). Observed network measurement data may be collected which includes a first signal characteristic from the mobile's serving transmitter (operation **803**). The observed network measurement data may be modified as a function of the first signal characteristic (operation **805**), for example the first signal characteristic may be received power and the modification may be a function of the relative value with respect to the received power. The modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **807**)

FIG. **9** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of calibration data for a region may be provided (**901**). Network measurement data from transmitters may be observed and collected including a signal characteristic from each of the transmitters (operation **903**). An average value for the signal characteristic among the transmitters may be determined (operation **905**). The average for the signal characteristic may be a weighted average. The observed network measurement data may be modified using the determined average value (operation **907**) and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **909**)

FIG. **10** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of previously-gathered outdoor calibration data for a predetermined region in a wireless network may be provided (operation **1001**). Network measurement data may be observed and collected (operation **1003**). The network measurement data may be compared with the database of calibration data to thereby determine a plurality of location estimates for the mobile station (operation **1005**). The location estimates may be derived using modified, unmodified, limited signal characteristics, several signal characteristics, etc. For each location estimate, a confidence measure may be determined (operation **1007**). A location may be determined based on the plurality of location estimates and their respective confidence measures (**1009**). For example, the location may be determined based on a weighted average, where the weights are directly proportional to the confidence measures.

The embodiments described above may be used in communication devices, such as, a base station, having varying configurations that include, but are not limited to: predetermined calibration data collected over varying terrain, different base station configurations, varying cellular communication protocols, etc.

While preferred embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalents, many variations and modifications naturally occurring to those skilled in the art from a perusal hereof.

What is claimed is:

**1**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a first transmitter and a second transmitter;

collecting observed network measurement data including a first signal characteristic from said first transmitter and a second signal characteristic from said second transmitter;

determining which of said first and second signal characteristics has a greater magnitude;

modifying said observed network measurement data using the greater magnitude signal characteristic; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**2**. The method of claim **1** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**3**. The method of claim **1** wherein said observed network measurement data includes data collected at the mobile station.

**4**. The method of claim **1** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**5**. The method of claim **4** wherein said observed network measurement data is collected at a mobile station located within a structure.

**6**. The method of claim **4** wherein said first signal characteristic is signal strength.

**7**. The method of claim **6** wherein said second signal characteristic is signal strength.

**8**. The method of claim **7** wherein the modifying of said calibration data uses a difference between said first or second signal characteristics.

**9**. The method of claim **7** wherein said first signal characteristic is signal strength of a control channel transmitted by said first transmitter and received by said mobile station.

**10**. The method of claim **9** wherein said second signal characteristic is signal strength of a control channel transmitted by said second transmitter and received by said mobile station.

**11**. The method of claim **1**, wherein the observed network measurement data includes received signal strength of said transmitters as said mobile station.

**12**. The method of claim **1** wherein said observed network measurement data includes a data set comprising:

$$[P_1, P_2 \ldots, P_n, TA]$$

where:

$P_1$ represents the signal strength of said first transmitter as measured at said mobile station,

$P_2$ represents a signal strength of said second transmitter as measured at said mobile station wherein $P_2 > P_1$

$P_n$, represents a signal strength of a $n^{th}$ transmitter as measured at said mobile station wherein $P_{2>Pn}$, and

TA represents a timing advance parameter;

and wherein said modified network measurement data includes a data set comprising:

$$[P_2-P_1, 0, P_2-P_n, TA]$$

where:

$P_2-P_1$ represents a difference between $P_2$ and $P_1$,

0 represents a difference between $P_2$ and $P_2$, and

$P_2-P_n$ represents a difference between $P_2$ and $P_n$.

**13**. The method of claim **12** wherein said first transmitter is a serving transmitter for said mobile station and said second and third transmitters are neighboring transmitters.

**14**. The method of claim **12** wherein said third transmitter is not a member of said wireless network.

**15**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered outdoor calibration data for a predetermined region in a wireless network;

collecting network measurement data;

comparing said network measurement data with said database of calibration data to thereby determine a plurality of location estimate of the mobile station

determining a confidence measure for each of the plurality of location estimates;

determining the location of the mobile station based on the plurality of location estimates and the respective confidence measures.

**16**. The method of claim **15**, wherein the step of determining the location based on the plurality of location estimates and the respective confidence measures comprises selecting the location estimate having the highest respective confidence measure as the location of the mobile station.

**17**. The method of claim **15**, wherein the step of determining the location based on the plurality of location estimates and their respective confidence measures comprises weighing the plurality location estimates based on their respective confidence measures and obtaining a weighted average as the location of the mobile.

**18**. The method of **15**, wherein the confidence measures comprises one or more of the group consisting of a pdf the Mahalanobis distance, and a distortion measure.

**19**. The method of claim **15**, wherein the step of collecting network propagation data further comprises modifying the network propagation data.

**20**. The method of claim **15**, wherein the step of comparing said network propagation data with said database of calibration data to thereby determine a plurality of location estimate of the mobile station, further comprises modifying said calibration data prior to the comparison.

**21**. The method of claim **20**, wherein the step of comparing said network propagation data with said database of calibration data to thereby determine a plurality of location estimate of the mobile station, further comprises modifying said calibration data prior to the comparison.

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# (12) EX PARTE REEXAMINATION CERTIFICATE (10261st)

# United States Patent

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(54) **METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT**

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(52) **U.S. Cl.**
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(58) **Field of Classification Search**
None
See application file for complete search history.

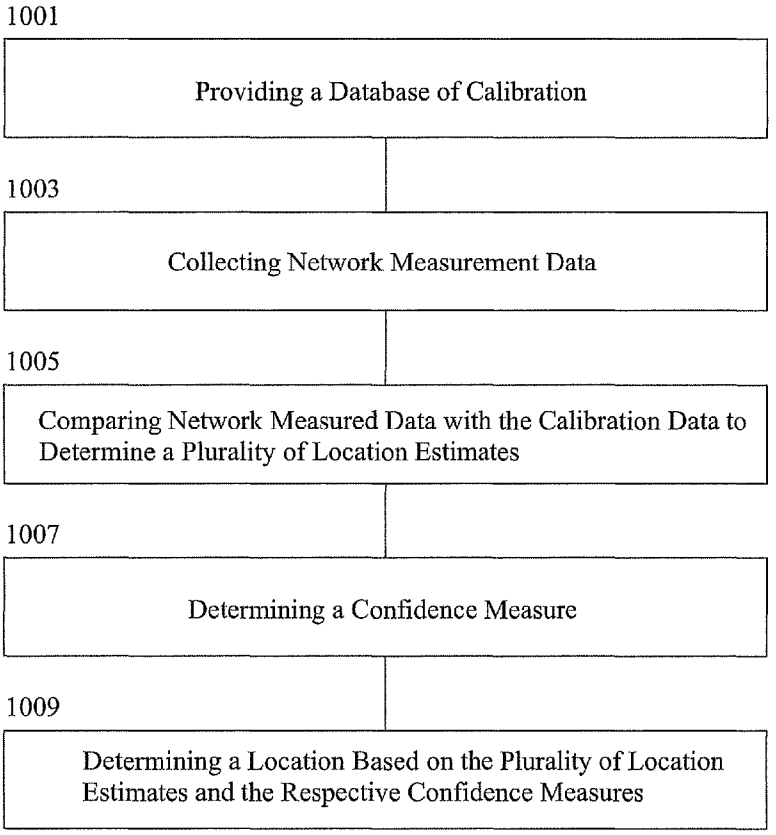
(56) **References Cited**

To view the complete listing of prior art documents cited during the proceeding for Reexamination Control Number 90/012,694, please refer to the USPTO's public Patent Application Information Retrieval (PAIR) system under the Display References tab.

*Primary Examiner* — Angela M Lie

(57) **ABSTRACT**

A method of modifying calibration data used to geo-locate a mobile station located in an indoor environment is disclosed. When a mobile station is located indoors, the signal strength of signals received and/or transmitted by the mobile station have the tendency to be lower than the strength of the signals received by a mobile station located outdoors. As a result of these lower signal strengths, geo-location efforts which rely on signal strengths may result in unsatisfactory location accuracy. Modifying pre-existing calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics.



# EX PARTE REEXAMINATION CERTIFICATE ISSUED UNDER 35 U.S.C. 307

THE PATENT IS HEREBY AMENDED AS INDICATED BELOW.

AS A RESULT OF REEXAMINATION, IT HAS BEEN DETERMINED THAT:

The patentability of claims **1-14** is confirmed.

Claims **15-21** are cancelled.

* * * * *

US008400358B2

(12) **United States Patent**
**Alles et al.**

(10) **Patent No.: US 8,400,358 B2**
(45) **Date of Patent: *Mar. 19, 2013**

(54) **METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT**

(75) Inventors: **Martin Alles**, Vienna, VA (US); **John Carlson**, Dulles, VA (US); **George Maher**, Herndon, VA (US); **Selcuk Mazlum**, Leesburg, VA (US)

(73) Assignee: **Andrew LLC**, Hickory, NC (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 686 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **12/424,320**

(22) Filed: **Apr. 15, 2009**

(65) **Prior Publication Data**

US 2009/0201207 A1 Aug. 13, 2009

**Related U.S. Application Data**

(63) Continuation of application No. 12/026,333, filed on Feb. 5, 2008, now Pat. No. 7,561,104.

(60) Provisional application No. 60/899,379, filed on Feb. 5, 2007.

(51) **Int. Cl.**
***G01S 3/02*** (2006.01)

(52) **U.S. Cl.** ..... **342/451**; 342/457

(58) **Field of Classification Search** ..... 342/451, 342/457, 463–465; 455/456.1, 456.6, 457
See application file for complete search history.

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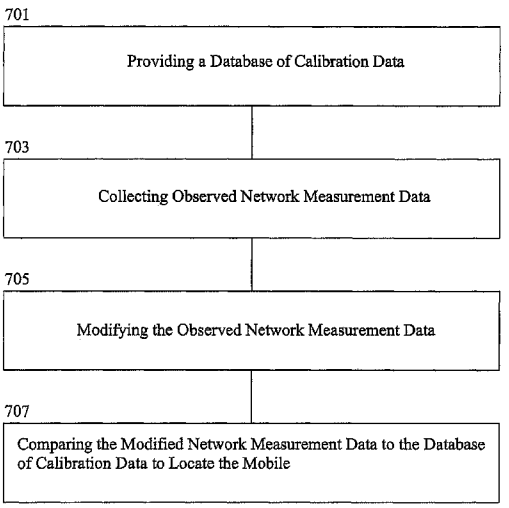
*Primary Examiner* — Dao Phan
(74) *Attorney, Agent, or Firm* — Duane Morris LLP

(57) **ABSTRACT**

A method of modifying calibration data used to geo-locate a mobile station located in an indoor environment is disclosed. When a mobile station is located indoors, the signal strength of signals received and/or transmitted by the mobile station have the tendency to be lower than the strength of the signals received by a mobile station located outdoors. As a result of these lower signal strengths, geo-location efforts which rely on signal strengths may result in unsatisfactory location accuracy. Modifying pre-existing calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics.

**52 Claims, 10 Drawing Sheets**



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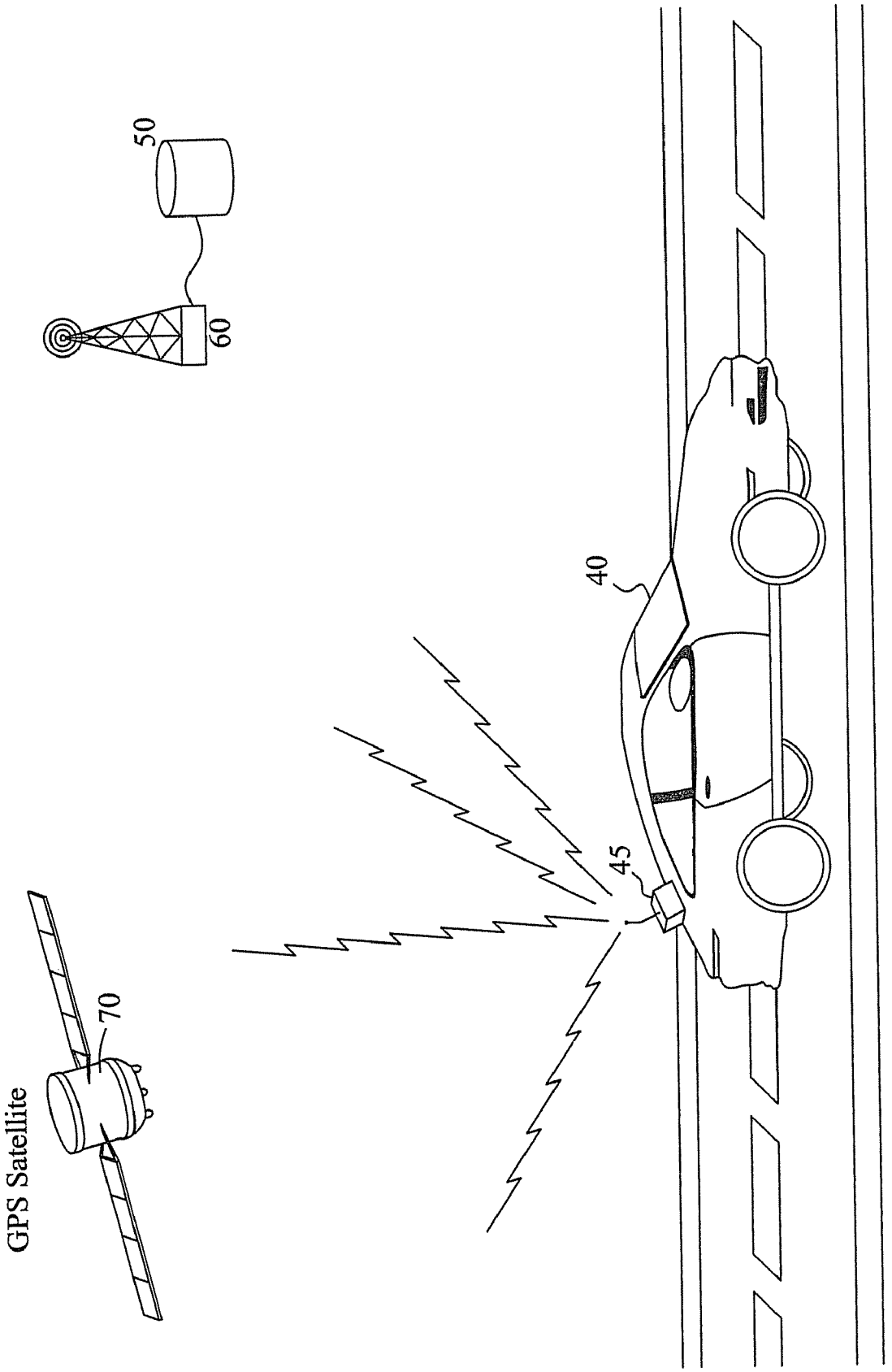


Figure 1

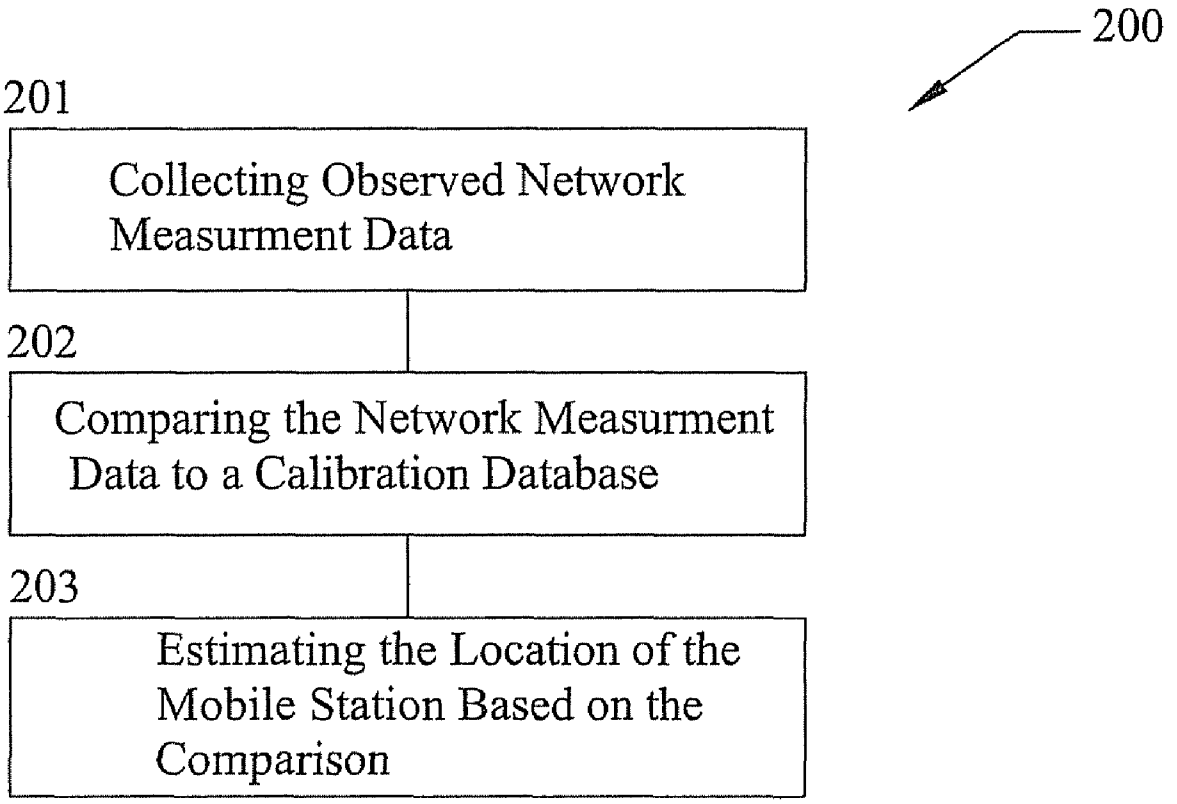
200
201
Collecting Observed Network Measurment Data
202
Comparing the Network Measurment Data to a Calibration Database
203
Estimating the Location of the Mobile Station Based on the Comparison

Figure 2

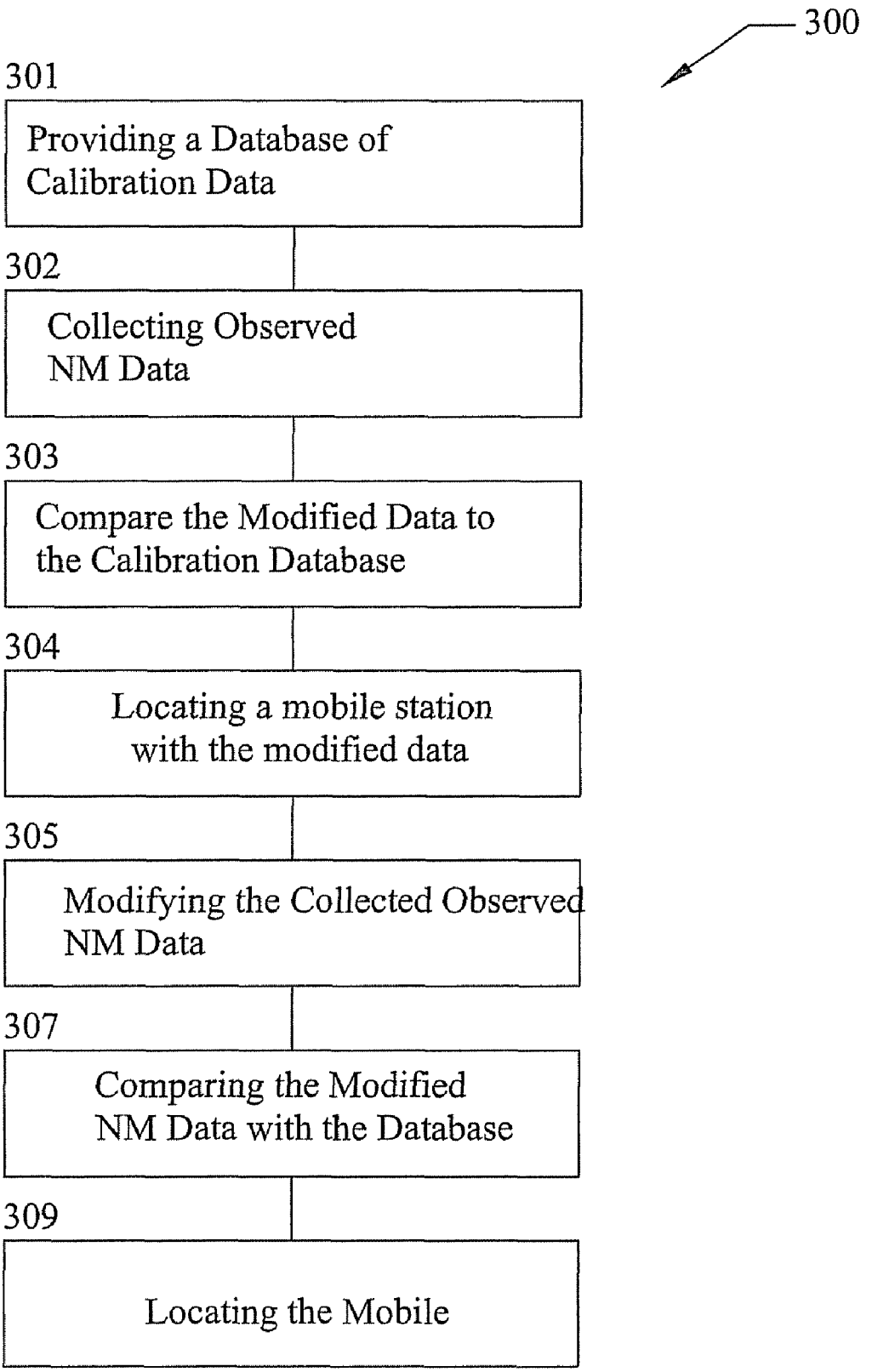
300
301
Providing a Database of Calibration Data
302
Collecting Observed NM Data
303
Compare the Modified Data to the Calibration Database
304
Locating a mobile station with the modified data
305
Modifying the Collected Observed NM Data
307
Comparing the Modified NM Data with the Database
309
Locating the Mobile

Figure 3

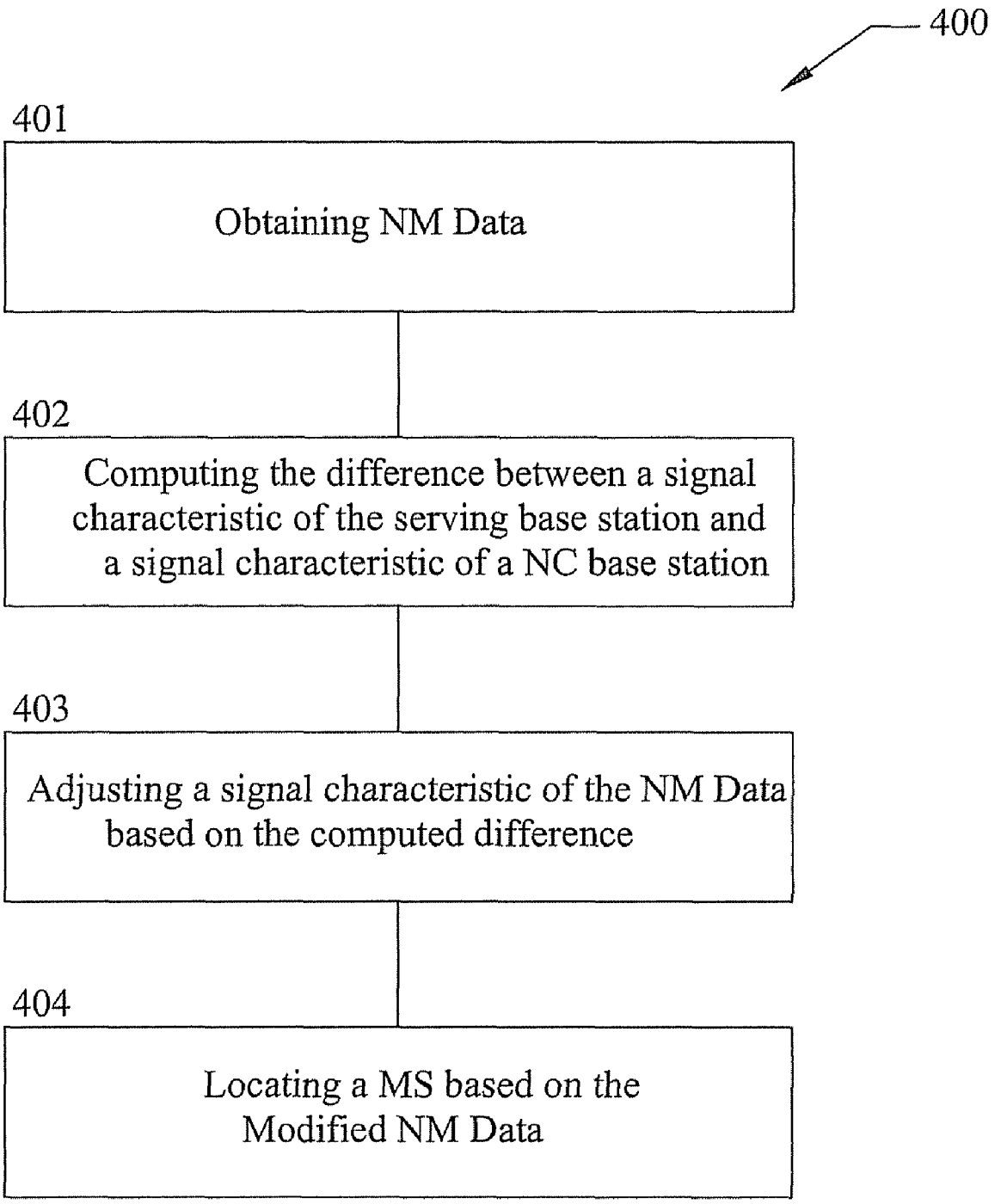
400
401
Obtaining NM Data
402
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station
403
Adjusting a signal characteristic of the NM Data based on the computed difference
404
Locating a MS based on the Modified NM Data

Figure 4

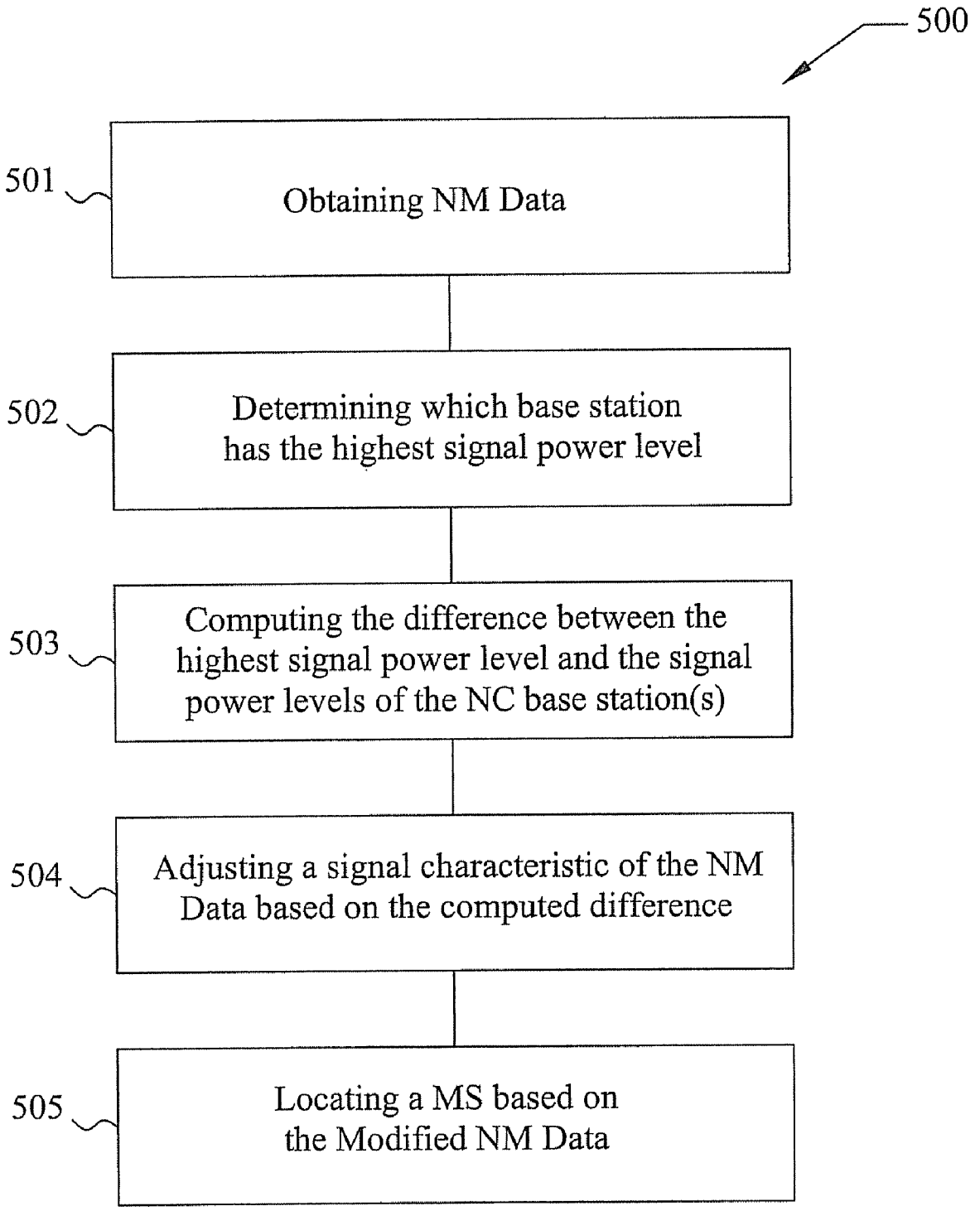
500
501
Obtaining NM Data
502
Determining which base station has the highest signal power level
503
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
504
Adjusting a signal characteristic of the NM Data based on the computed difference
505
Locating a MS based on the Modified NM Data

Figure 5

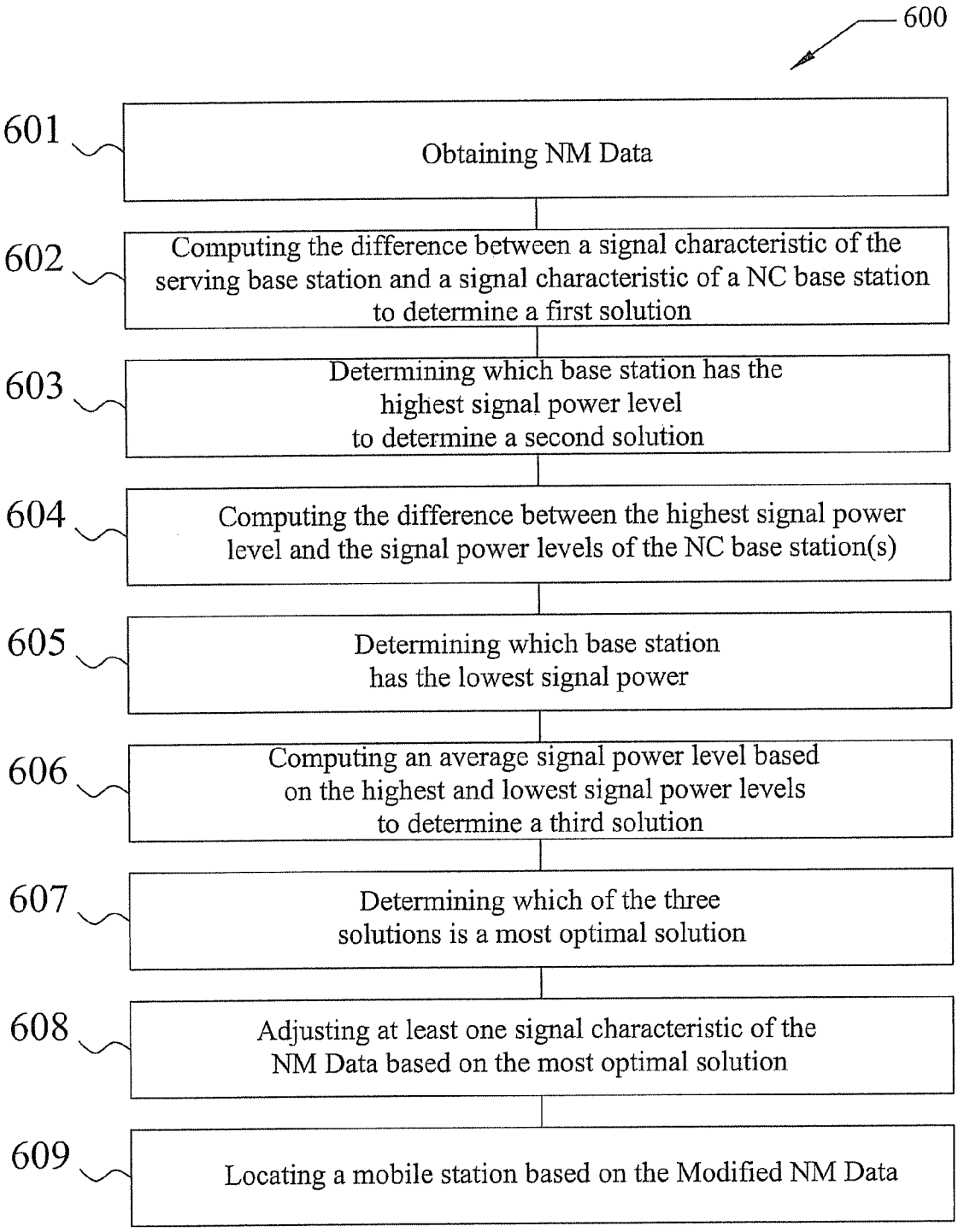
600
601
Obtaining NM Data
602
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station to determine a first solution
603
Determining which base station has the highest signal power level to determine a second solution
604
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
605
Determining which base station has the lowest signal power
606
Computing an average signal power level based on the highest and lowest signal power levels to determine a third solution
607
Determining which of the three solutions is a most optimal solution
608
Adjusting at least one signal characteristic of the NM Data based on the most optimal solution
609
Locating a mobile station based on the Modified NM Data

Figure 6

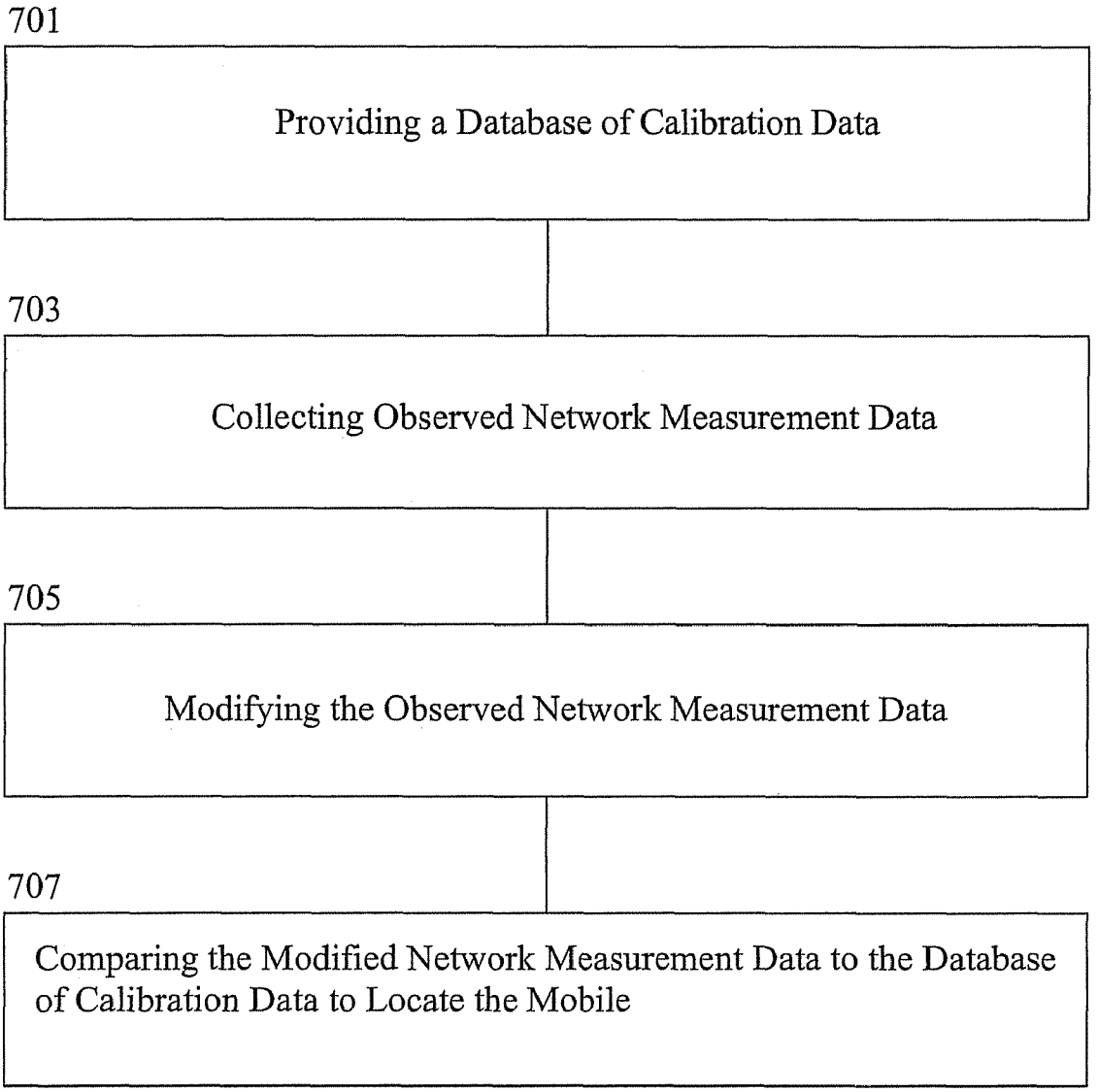
701
Providing a Database of Calibration Data
703
Collecting Observed Network Measurement Data
705
Modifying the Observed Network Measurement Data
707
Comparing the Modified Network Measurement Data to the Database of Calibration Data to Locate the Mobile

Figure 7

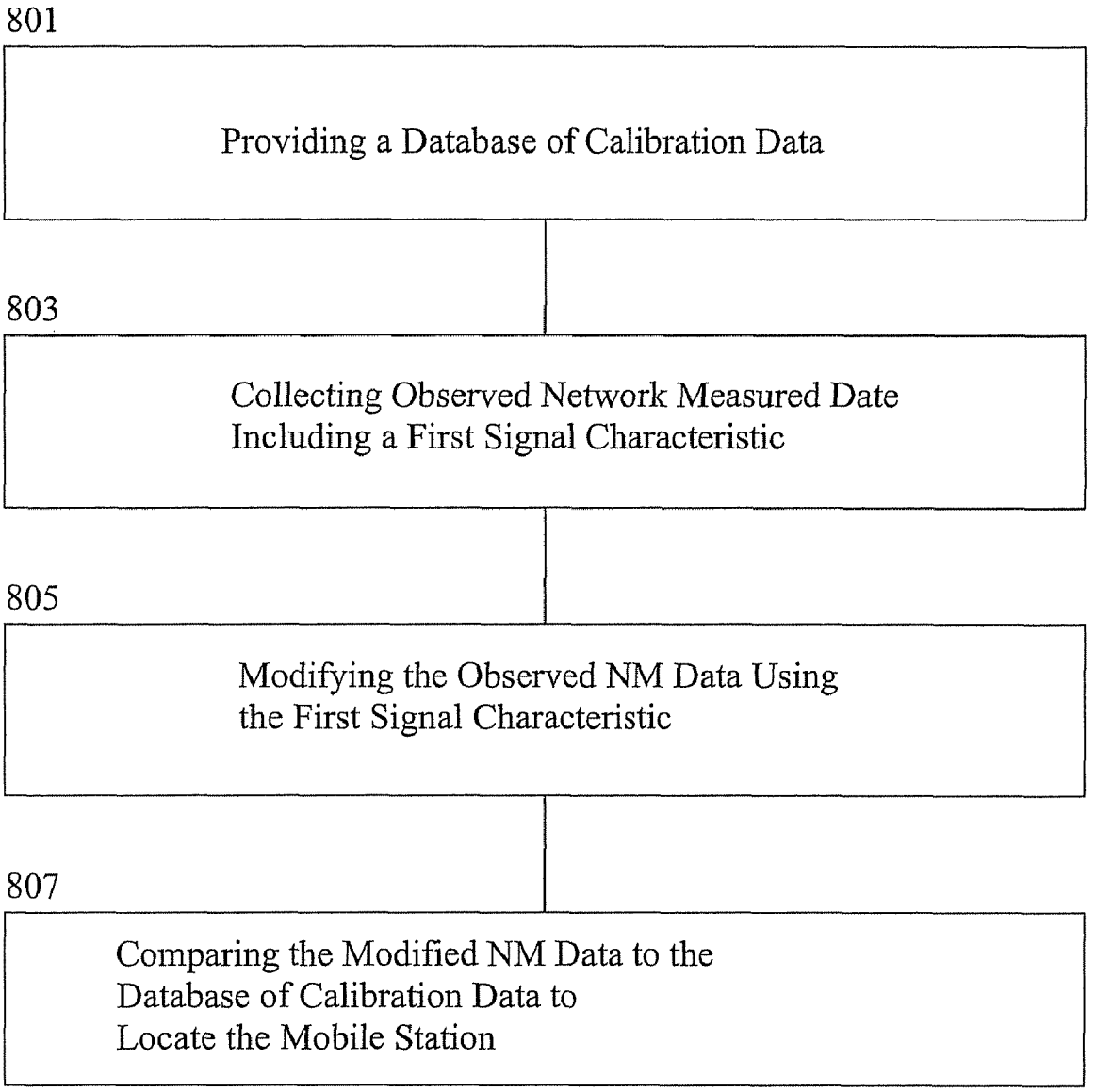
801
Providing a Database of Calibration Data
803
Collecting Observed Network Measured Date Including a First Signal Characteristic
805
Modifying the Observed NM Data Using the First Signal Characteristic
807
Comparing the Modified NM Data to the Database of Calibration Data to Locate the Mobile Station

Figure 8

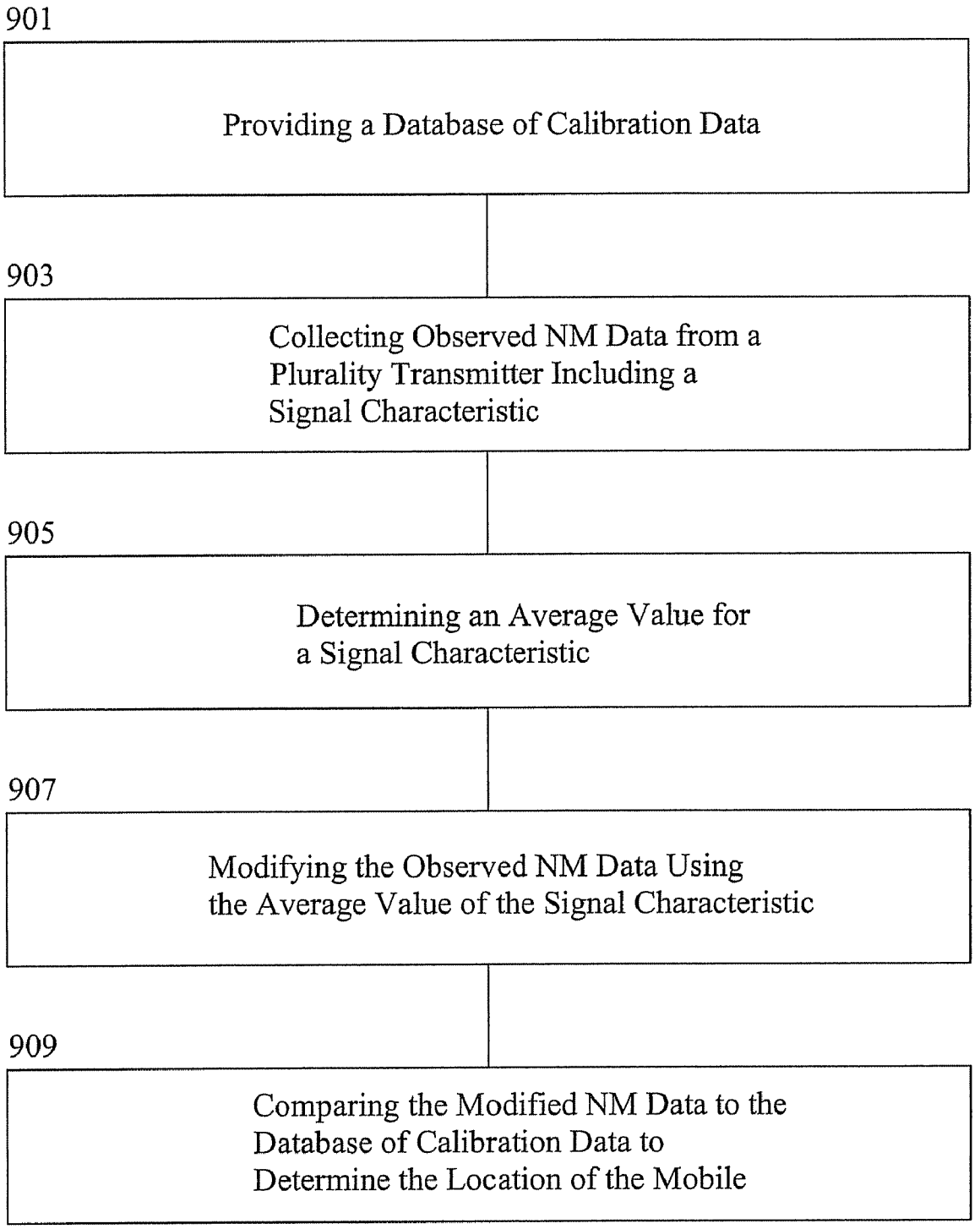
901
Providing a Database of Calibration Data
903
Collecting Observed NM Data from a Plurality Transmitter Including a Signal Characteristic
905
Determining an Average Value for a Signal Characteristic
907
Modifying the Observed NM Data Using the Average Value of the Signal Characteristic
909
Comparing the Modified NM Data to the Database of Calibration Data to Determine the Location of the Mobile

Figure 9

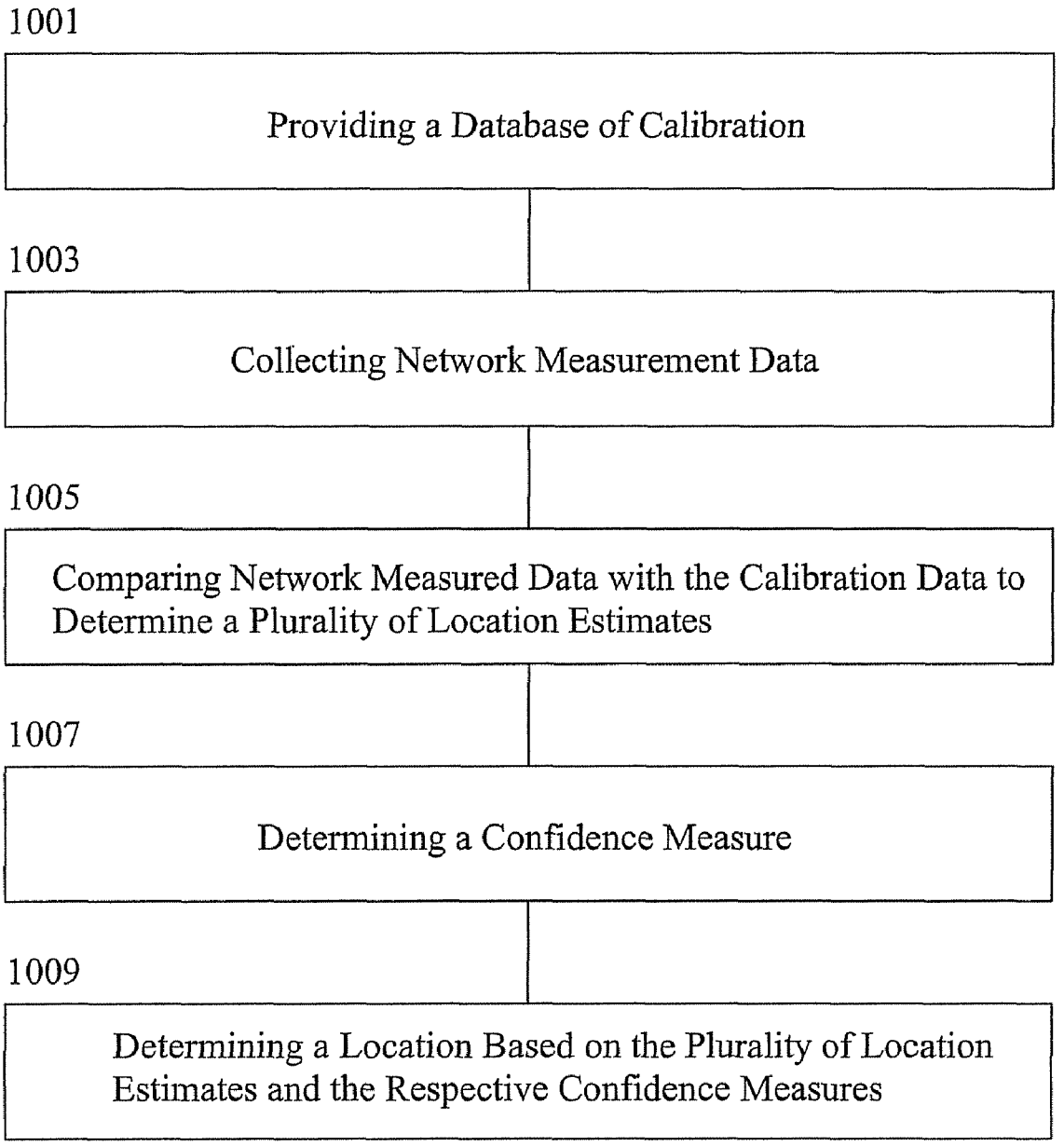
1001
Providing a Database of Calibration
1003
Collecting Network Measurement Data
1005
Comparing Network Measured Data with the Calibration Data to Determine a Plurality of Location Estimates
1007
Determining a Confidence Measure
1009
Determining a Location Based on the Plurality of Location Estimates and the Respective Confidence Measures

Figure 10

# METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT

## CROSS REFERENCES

The present application is a continuation application of and claims the priority benefit of U.S. application Ser. No. 12/026,333 filed Feb. 5, 2008, now U.S. Pat. No. 7,561,104 entitled "Method to Modify Calibration data Used to Locate a Mobile Unit," which is related to and claims the priority benefit of Provisional Application No. 60/899,379 entitled "Mobile Location Using Network Measurement Reports" filed on Feb. 5, 2007, each of which are hereby incorporated by reference in their entirety.

## BACKGROUND

The use of wireless communication devices such as telephones, pagers, personal digital assistants, laptop computers, etc., hereinafter referred to collectively as "mobile appliances" or "mobiles stations" has become prevalent in today's society. In recent years, at the urging of public safety groups, there has been increased interest in technology which can determine the geographic position or "geo-locate" a mobile station in certain circumstances.

Estimating the location or "geo-locating" a mobile station may require one or more types of calibration data associated with the mobile station (e.g., signal strength, round trip time, time difference of arrival (TDOA), etc.). Calibration data is typically collected in an outdoor environment. The primary reason for collecting calibration data outdoors is the greater ease of performing automated calibration collection procedures or, in some instances, manual collection procedures along roads. It is more time-consuming to perform calibration procedures indoors due to the required access to buildings and the inability to utilize automated collection procedures designed for outdoor environments.

When a wireless device is located indoors, the signal strengths of signals received from the serving and/or neighboring base stations tend to be lower than the strength of the signals received by a wireless device located outdoors. As a result of these lower signal strengths, performing comparisons between the received signal strengths of the indoor wireless device and signal strength data stored in a calibration database may result in a poor estimated location accuracy. Modifying the calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics. Calibration data collected in areas located adjacent to indoor facilities may be altered to increase the accuracy of location estimates of a mobile station located indoors.

One embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network and collecting observed network measurement data. The method also includes modifying the observed network measurements and then comparing the modified data with the database of calibration data to determine the location of the mobile station.

Another embodiment of the present subject matter is a system for determining a location of a mobile station. The system includes a database of previously-gathered calibration data for a region in a wireless network and circuitry such as a wireless receiver for collecting observed network measurement data. The system includes circuitry, such as a processor, for modifying the observed network measurement data; and



circuitry, such as a processor, for comparing the modified data with the calibration data in the database to determine the location of the mobile station.

Yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network which includes a serving transmitter. The method collects observed network measurement data including a first network characteristic from said serving transmitter and modifies the observed network measurement data using said first characteristic. The method compares the modified network measurement data with the database of calibration data to thereby determine the location of the mobile station.

Still yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network including a first transmitter and a second transmitter. The method also includes collecting observed network measurement data including a first and second signal characteristic from the first and second transmitters respectively and determining which of the first and second signal characteristics has a greater magnitude. The observed network measurement data may be modified using the greater magnitude signal characteristic, and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station.

A further embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network and collecting observed network measurement data from a plurality of transmitters which includes a signal characteristic from each one of said plural transmitters. The method also includes determining an average value for the signal characteristics and modifying the observed network measurement data using the average value. The method may then compare the modified network measurement data with the database of calibration data to determine the location of the mobile station.

Still a further embodiment of the present subject matter recognizes that it may be desirable to locate a mobile station by obtaining at least one network measurement report representing at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of neighboring base stations. The method may also compute the difference between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the neighboring base stations to determine a first solution and determine which neighboring base station has the highest signal power level at a particular location. The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be computed to determine a second solution. It may also be determined which neighboring base station has the lowest signal power level at the particular location. The method may also comprise computing an average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level to determine a third solution and determining which of the three solutions is a most optimal solution based on at least one comparison of the three solutions. At least one signal characteristic of the network measurement report may be adjusted based on the most optimal solution and the modified network measurement report may be utilized to locate a mobile station.

Another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered outdoor calibration data for a region in a wireless network, collecting network measurement data, and comparing the network measurement data with the database of calibration data to thereby determine several location estimates of the mobile station. The method may also include determining a confidence measure for each of the plurality of location estimates and determining the location of the mobile station based on the plurality of location estimates and their respective confidence measures.

These and other advantages of the disclosed subject matter over the prior art will be readily apparent to one skilled in the art to which the disclosure pertains from a perusal of the claims, the appended drawings, and the following detailed description of the preferred embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless communications networking environment.

FIG. **2** illustrates a flow diagram of an exemplary inventive concept.

FIG. **3** illustrates a flow diagram of another exemplary inventive concept.

FIG. **4** illustrates a flow diagram of yet another exemplary inventive concept.

FIG. **5** illustrates a flow diagram of still another exemplary inventive concept.

FIG. **6** illustrates a flow diagram of still yet another exemplary inventive concept.

FIG. **7** illustrates a flow diagram of an embodiment of the subject matter.

FIG. **8** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **9** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **10** illustrates a flow diagram of another embodiment of the subject matter.

## DETAILED DESCRIPTION

Calibration data samples obtained outdoors may be used to simulate indoor calibration data to locate a mobile station (MS) in an indoor facility. A method of utilizing calibration data samples to represent indoor and/or outdoor wireless networking environments is described herein.

Reliably locating a mobile station located indoors, even when the calibration data has been obtained in an outdoor environment, may simplify a calibration collection procedure. Calibration data obtained outdoors may be modified and substituted for indoor calibration data. In addition network measurement data may be modified for comparison with the outdoor calibration data.

In general, a non-uniform grid point (NUG) may represent the signal characteristics and/or calibration data over a given region. As illustrated in FIG. **1**, a set of NUGs (NUG**1**, NUG**2** and NUG**3**) are shown as being a part of a larger geographical region (R), which includes various wireless networking components (e.g., (MS **11** and BS **20**—NUG**1**), (MSs **12**-**15**—NUG**2**) and (MSs **16**-**18** and BS **30**—NUG**3**)). The NUGs represent an area of collected calibration data, which may be stored in a database for easy retrieval during a calibration data comparison operation between the NUG and a received network measurement report (NMR).

Calibration data may be obtained from data collection devices during field test operations, and/or from MSs or other communication devices within the general area of the NUG. Cross-NUG communications may occur between MSs and/or BSs located within communication range of one or more of the NUGs. For example, BS **10** may be located outside the region (R) and may communicate with one or more devices located in the various NUGs **1**-**3**. The different NUGs **1**-**3** may be separately defined by a variety of parameters. For example, geographical areas (e.g., mountains, buildings, roads) may be a factor in deciding the boundaries of a NUG. Additionally, varying concentrations of MSs may be another factor that separates one NUG from another.

Network measurement reports (NMRs) may be used to represent network characteristics at particular locations within a given region (R). Any point located within a NUG may have corresponding signal strength levels that represent the signal power of the serving and/or neighboring cell (NC) BSs. An exemplary NMR may be represented by example_data_vector=[P**1**, P**2**, P**3**, TA**1**]. Referring to FIG. **1**, the power level signals (P**1**-P**3**) may represent the power levels of the three BSs **10**, **20** and **30**, as measured at a particular location. The timing advance parameter TA**1** (or equivalent parameter) may be used to represent timing information of signals transmitted between the MS and one or more BSs.

The value of the timing advance (TA) parameter corresponds to the length of time a signal from a MS takes to reach a particular BS. A MS may be configured to transmit data signals at specific timeslot intervals depending on the type of wireless communication protocol employed (e.g., TDMA, GSM, 3GPP etc.). Using the speed of light (c=3*10^8 m/s) as a reference velocity for the radio waves, the TA parameter may be increased or decreased depending on the distance between the MS and the BS. The TA parameter may be periodically adjusted as the distance from the MS to the BS changes. Of course, a NMR may contain any number and type of parameters, and may be used to estimate the location of a MS.

For example, NMR(s) may be transmitted from the MS or from other wireless communication components to position determining equipment (PDE) **50**, which processes the received NMR information and may attempt to locate the position of the MS. NMR(s) may be periodically generated by MSs or other communication devices to calibrate the NUG. The NUG may also be based entirely on information received from NMR(s) generated by MSs located in the NUG.

The received Network Measurement data (NM data) may be compared to predetermined calibration data representing one or more NUGs to estimate the location of a MS. In a case where NM data is compared against a NUG, like parameters may be compared to estimate if the target MS **18** is within the NUG. Similarly, NUG parameters may be computed in response to a comparison operation, and then compared to the NM data. Each NUG may have a series of parameters and/or functions characterizing one or more particular locations in the NUG. Given a received set of one or more NMR(s) obtained from some unknown location, an estimate of that unknown location may be calculated using the characterization of the NUG or uniform grid (UG) over that region.

It may be desirable to use the original unmodified NM data directly without modification when locating a mobile station. Assuming the MS is located in an indoor facility, the data contained in the NMR(s) may be a function of calibration data collected outdoors. In some cases, the unmodified outdoor calibration data used to represent the indoor facility may

provide an accurate representation of the location of the target MS **18** (e.g., low distortion structures, open-faced facilities, etc.).

Referring to FIG. **1**, the NM data may be sent from the target MS **18** to the BS **10**, where the PDE **50** processes the NMR and performs one or more comparison operations between the NM data and the calibration data of the NUG(s). Once the comparison operation is complete, the location of the target MS **18** may be estimated. A direct comparison of the original NM data may be made against the corresponding NUG(s) characteristics. Alternatively, the NM data may not be modified even if NUG(s) are utilized to estimate the location of the mobile station.

NM data may also be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations. For example, differences in parameters between the serving cell and the NC may be calculated and the quantities used to modify the original NM data.

If an original NMR received at the PDE **50** had the form NMR**1**=[P**1**, P**2**, P**3**, TA**1**], where P**1** is the serving BS power at a particular location, P**2** is a first NC power, P**3** is a second NC power, and TA**1** is the timing advance parameter, the modified NMR may be represented by: NMR_modified=[0, P**1**-P**2**, P**1**-P**3**, TA**1**]. The resulting data vector may be used to calculate new relative power levels of the NC BSs by subtracting or adding the NMR_modified parameters from the original NMR**1** parameters. In this example, the power of the serving BS may be used as a basis to obtain relative power level modification parameters to modify the NC power level parameters of NMR(s).

The calculated modified parameters (NMR_modified=[0, P**1**-P**2**, P**1**-P**3**, TA**1**]) may also be used to simulate an indoor facility by modifying NMR(s) received from an indoor location. Alternatively, the modified parameters may be used to conduct other calculations to obtain a desired set of modified results. For example, the modified NMR may be compared to one or more of the NUG(s) to provide an estimated location of a MS. Of course, the serving BS power level is not a required parameter to be used as a basis to obtain relative power level modification parameters, and many other parameters may be used to modify the NM data to simulate an indoor facility.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevServing_WD represents the received signal strength of the serving base station's control channel measured by the wireless device at an unknown location. Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel, RxLevServing_DB represent the average received signal strength of the serving station's control channel, stored in a database of the PDE **50** during the calibration process, and RxLevNeigh_i_DB represent the average received signal strength of the $i^{th}$ neighbor's control channel stored in the database during a calibration process (i=1 to N, where N is the number of neighbor cells reported).

A comparison operation may be conducted between the received signal strengths of the NC-BSs relative to the serving BS's received signal strength. For example, a comparison may include computing the difference between the parameters of the serving base station and the $i^{th}$ neighbor's parameters (i.e., (RxLevServing_WD-RxLevNeigh_i_WD) and (RxLevServing_DB−RxLevNeigh_i_DB)). Once the differences are calculated, the magnitudes of the differences may be compared to a predetermined threshold value used to distinguish between an acceptable difference value requiring no modification to the NM data and a non-acceptable difference value invoking further modification efforts.

NM data may be modified by an amount relative to the signal strength of a NC-BS. In this example, the NC-BS having the highest signal power may be used as a basis to modify the values of the NM data. The differences between the NC having the highest cell power and the cell powers of the remaining NC-BSs may be calculated and the quantities thereof used to modify the original NM data.

An exemplary NMR may have the form NMR=[P**1**, P**2**, P**3**, P**4**, TA**1**], where P**1** is the serving BS signal power, P**2** is a NC having the highest signal power at the intended location of the NMR, P**3** and P**4** are different NC signal powers, and TA**1** is a timing advance parameter. In this example, P**2** has the highest signal power level and may be used as the basis for modifying the parameters of the NMR. The modified NMR may then be represented by NMR_modified2=[P**2**-P**1**, 0, P**2**-P**3**, P**2**-P**4**, TA **1**]. The resulting data vector NMR_modified2 may be used to calculate new power levels of the NC base stations by subtracting or adding the NMR_modified2 parameters to the original NMR parameters.

The modified NMR may be compared to one or more of the NUG(s). In the previous examples, the power of the serving BS and the NC with the highest signal power level were used to obtain the relative power modification quantities. The signal power level of the serving BS and/or the NC having the highest signal power may be used solely to modify the NMR, and may not be included in comparison operations against the NUG(s). If the serving BS power level parameter and/or the NC having the highest signal power level parameter are excluded from the comparison to the NUG(s), the first and/or additional terms of the NMR may be ignored during the comparison operation. Of course, any other parameter may be utilized and the example above including power level should not limit the scope of the claims appended herewith.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevNeigh_h_WD represents the received signal strength of a neighboring BS's control channel (neighbor A) having the highest signal level, as measured by the wireless device. RxLevNeigh_h_WD may be listed first in a measurement report list containing signal strengths sorted in descending order (h=1). Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel measured (neighbor i, where i≠h), as by the wireless device, and RxLevNeigh_h_DB represent the received signal strength of the neighbor (neighbor A) with the highest received signal strength, as measured by the wireless device, and which may be stored in the PDE **50** database during a calibration process. RxLevNeigh_i_DB may be used to represent the received signal strength of the $i^{th}$ neighboring BS's control channel (neighbor i, where i≠h, and i=1 to N, and where N is the number of neighbors reported). RxLevNeigh_i_DB may be stored in the PDE **50** database during a calibration process.

In this example, correlation may be conducted over the received signal strengths of the NC-BSs relative to the NC-BS having the highest received signal strength, as observed by the wireless device. A comparison may include computing the difference between the parameters of the serving BS and the $i^{th}$ neighbor's parameters (i.e. (RxLevNeigh_h_WD-RxLevNeigh_i_WD) and (RxLevNeigh_h_DB-RxLevNeigh_i_DB)). Comparisons may also be conducted for any one, combination of or all of the measured parameters of the NC-BSs.

NM data may be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations by an amount relative to the average signal strength of one or more NC base stations. Each signal power or parameter component of the NMR may also be modified by an average

signal power or parameter level based on one or more of the measured NC signal power levels. The average received signal power level may be calculated a number of different ways, for example, the average of the two highest signal powers, the three highest powers, the average of all (N) signal powers, or an intermediary number between one or more of the measured NC signal power components. Modifying the original NMR components may include subtracting or adding to the existing NMR power components by an amount based on the calculated average, or other various known functions.

To further illustrate modification of the NMR, consider a particular implementation where RxLevNeigh_avg_WD represents the average received signal strength based upon a number of control channel signal powers of neighboring BSs, as measured by the wireless device at an unknown location to be estimated. Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel signal power, and RxLevNeigh_avg_DB represent the average received signal strength of data stored during calibration, and computed based on the neighboring BSs, as measured by the wireless device and used in computing the average received signal strength. The same neighboring BSs may be used to represent the average received signal strength of the signal power levels received by the wireless device and for the average received signal strength of calibration data stored in the PDE **50** database. Let RxLevNeigh_i_DB represent the received signal strength of the $i^{th}$ neighbor's control channel stored in the PDE **50** database during the calibration process (i=1 to N, where N is the number of neighbors reported).

In this example, a comparison may be conducted over the received signal strengths of the neighboring BSs relative to the average received signal strength computed for all neighboring BSs observed by the wireless device (i.e., compare between (RxLevNeigh_avg_WD-RxLevNeigh_i_WD)) and for all neighbors previously measured by the wireless device (i.e., compare between (RxLevNeigh_avg_DB-RxLevNeigh_i_DB)). The average signal power level observed over all the neighbor signal power levels may be realized in absolute powers (mW) or in relative powers (dBm).

Any combination of the above NMR modification procedures may be performed to increase the accuracy of mobile station location estimates. Further, any number of or type of parameters may be utilized in any of the aforementioned procedures and the exemplary parameters of power level, signal strength, etc. should not limit the scope of the claims appended wherewith. Certain factors impacting the modification procedure selection process may include the specific type of cellular technology, the geographical terrain and/or environmental conditions, etc. Further, the present subject matter acknowledges that some NMR modification procedures may be best suited for outdoor location estimation, while others are better suited for indoor location estimation, and some even may be best for mixed (indoor & outdoor) location estimation.

For example, if the serving BS for a mobile station is known to be in an area where there are no buildings or obstructions then it may be prudent to leave the NM data unmodified or select the NMR modification procedure where the serving base station is used as the basis to calculate NMR modifications. Further, if the serving cell is in a geographical area with known large obstructions (e.g., buildings, mountains etc.) then it may be prudent to use the NMR modification procedure that selects the NC base station having the highest signal power as the basis to calculate NMR modifications. Additionally, if the serving cell is in an area containing both outdoor and indoor facilities, then it may be best to use the average of more than one NC signal power value as the basis to modify the NMR(s).

Regardless of the type of modification algorithm selected to modify the NM data, a margin of error may still be present when attempting to determine the precise location of a mobile station. Determining the amount of location error may be useful when estimating the likelihood of accurately locating a mobile station. A confidence measure may also be used to represent the accuracy of a mobile station's estimated location.

The value of a confidence measure may vary depending on the estimated accuracy of the location estimated. If estimated locations derived from mapping NM data to a given location, whether using a NUG or other form of a data source for comparison purposes, agree under any or all combinations, the respective confidence measure "C" may be considered high. A confidence measure may also be represented as a function that increases as the quantity of measured data correctly matches data associated with a final estimated location. An exemplary confidence measure or function may be represented as a fraction of all locations that are similar to the final estimated location, however, such an example should not limit the scope of the claims appended herewith.

After one or more of the data modification procedures have been calculated, respective confidence measures may be calculated to represent the likely accuracy of the modification procedures. Confidence measures may then be compared and the best one selected to represent the appropriate modification procedure to implement.

Certain estimated locations may be assigned weights by using a confidence measure as a weight to represent the probability of locating a mobile station at a given location. For example, confidence measures may be based on one or more calculated parameters, including, but not limited to: a probability density function (PDF), a joint PDF, Mahalanobis distance, distortion measure, ordered number parameter, timing advance (TA) parameter, mobile orientation etc. The calculated parameters may be derived from the NUG calibration data stored in the PDE **50** database. The parameters may be pre-stored in memory or may be calculated during a NMR to NUG comparison operation.

Probability density functions may be calculated based on an individual NC base station power level, or a set of multiple NC base station power levels. The calculated probability density function may be compared to the set of available NUGs (i.e., NUGS **1-3** of FIG. **1**) to determine a probability that the NM data matches a particular NUG location. A joint probability may also be calculated over a set of probabilities to further estimate the location of the mobile station. The results of the calculated PDF may be used in a number of estimation techniques to locate the mobile station.

Distortion measures may be determined at a particular location may be included in a NMR and used in a comparison operation to measure the difference in distortion between NUG data and NM data. The distortion measures may be used to estimate a location of a mobile station based on the results of the comparison.

A Mahalanobis distance may be an exemplary distortion measure and may utilized to assist in identifying and analyzing different patterns in a wireless communications environment. The Mahalanobis distance may also be useful in determining similarities between an unknown sample data set and a known data set.

Ordering number lists may also be used to organize parameters for comparison purposes. An ordering number list may be a list or table of data parameters organized in a particular

order. The power levels may be listed in descending order and compared to similar parameters associated with a NUG(s). A threshold power level may be used to represent an acceptable amount of deviation between a comparison of power levels obtained from a NMR(s) and/or a NUG(s). If one or more power levels in the NMR(s) and the NUG(s) fall within an acceptable range of one another, the location of a mobile station may be measured with a corresponding degree of accuracy.

Each generated NMR may be used to provide an individual estimate of the mobile station's location. The PDE **50** may receive a number of NMRs over a period of time, a corresponding number of location estimates may be generated based on the number of NMRs received. These estimates may be combined in a statistical algorithm and may provide a more accurate location estimate than the individual NMRs.

Given a particular NMR or set of NMR(s) containing data collected outdoors, a selection procedure may be conducted to select the most appropriate modification procedure to use when modifying the NM data. Once one or more of the above described NMR modification procedures have been calculated, (e.g., non-modification, serving cell power level, highest NC power level, average(s) of the NC power levels, etc.) one or more of these calculations may be selected as an optimal solution to be used to modify the NMR.

One way to determine the optimal solution that should be used to modify the NMR is to calculate a confidence measure for each of the calculated modification procedures. Once the confidence measures have been calculated, the optimal solution may be selected as the modification procedure with the highest confidence measure. Alternatively, a location estimate may be made by weighting the individual solutions by the applicable confidence measure and combining the results into a single NMR solution.

Combining multiple NMR(s) may generate a location estimate with increased accuracy. When comparing NM data to a NUG, the grid point data that most closely matches the NM data may become the estimated location of the mobile station. In an alternative arrangement, interpolation may be used for determining a location that falls between two grid points to provide an even more accurate location estimate. Applying probabilistic weights, hypotheses and deriving confidence measures may increase the accuracy of the location estimates. Utilizing exemplary probabilistic measures, the estimated location of a mobile station may be determined within a particular degree of certainty. A similar approach may also be applied to select the appropriate NMR modification procedure to accommodate for varying conditions and other operational variables (e.g., different air standards, varying environmental circumstances, etc.).

FIG. **2** illustrates a flow diagram **200** of a method to locate a mobile station. Observed network measurement data may be collected (operation **201**). The observed data would typically be the same or similar to the data in a network measurement report (NMR). The network measurement data represents at least one network characteristic observed by the mobile station operating at a particular location within a region. The NM data may be compared to calibration database data, where the calibration database data represents calibration data measured within the geographical area of the region (operation **202**). The location of the mobile station may be estimated based on the comparison of the modified network measurement data and the calibration database data (operation **203**).

FIG. **3** illustrates a flow diagram **300** of a method to locate a mobile station in an indoor environment. Calibration data samples are collected in an outdoor environment (operation **301**). At least one attenuation variable may be applied to the calibration data sample to simulate an indoor environment (operation **302**). The modified network measurement data sample may be applied to a mobile station location algorithm (operation **303**). The mobile station may be then located in the indoor environment based on the mobile station location algorithm implementing the at least one modified calibration sample (operation **304**).

FIG. **4** illustrates a flow diagram **400** of a method to locate a mobile station. NM data may be obtained to represent at least one network characteristic of the mobile station's serving base station and at least one second network characteristic of at least one of the mobile station's neighboring base stations (operation **401**). The difference between the at least one first signal characteristic and the at least one second signal characteristic may be computed (operation **402**). At least one signal characteristic of the NM data may be adjusted based on the computed difference (operation **403**). The mobile station may be then located based on the modified network measurement data (operation **404**).

FIG. **5** illustrates a flow diagram **500** of a method to locate a mobile station. NM data may be obtained (operation **501**), which represents at least one first network characteristic of the mobile station's serving base station, and at least one second and third network characteristic of the mobile station's at least two neighboring base stations. It may be then determined which base station has the highest signal power at a particular location (operation **502**). The difference between the highest signal power at the particular location and the power levels at the particular location of the serving base station and the remaining neighboring base stations may be determined (operation **503**). At least one signal characteristic of the NM data may be adjusted based on the computed differences (operation **504**). The mobile station may then be located based on the modified NMR (operation **505**).

FIG. **6** illustrates a flow diagram **600** of a method to locate a mobile station. A NMR may be obtained (operation **601**), which represents at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of the mobile station's at least two respective neighboring base stations. A difference may be computed between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the mobile station's neighboring base stations to determine a first solution (operation **602**). It may then be determined which base station has the highest signal power level at a particular location (operation **603**). The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be determined as a second solution (operation **604**). The neighboring base station having the lowest signal power level at the particular location may be determined (operation **605**). An average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level may be determined as a third solution (operation **606**). It may then be determined which solution is a most optimal solution by comparing the three solutions (operation **607**). The signal characteristic of the NM data may then be adjusted based on the most optimal solution (operation **608**). The mobile station may then be located based on the adjusted NM data (operation **609**).

FIG. **7** illustrates an embodiment of the present subject matter. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network (operation **701**). The database may be a collection of data from uniform or non-uniform grids that

contain network measurements with associated location estimates. Network measurement data may be then observed and measured typically by a mobile station or any other wireless device (operation **703**). The network measurement data may include received base station power and timing advance, as well as other network characteristics observable by a mobile station. The observed network measurement data may then be modified (operation **705**). This modification may include applying an attenuation function to some or all of the network measurement data or converting absolute values into relative values. The modification may be performed by a processor, microprocessor or ASICS. The modified network measurement data may then be compared to the calibration database in order to determine the location of the mobile station (operation **707**). The comparison may be performed by a processor, microprocessor or ASICS.

FIG. **8** is another illustration of an embodiment of the present subject matter. A database of previously-gathered calibration data for a predetermined region in a wireless network may be provided (operation **801**). Observed network measurement data may be collected which includes a first signal characteristic from the mobile's serving transmitter (operation **803**). The observed network measurement data may be modified as a function of the first signal characteristic (operation **805**), for example the first signal characteristic may be received power and the modification may be a function of the relative value with respect to the received power. The modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **807**).

FIG. **9** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of calibration data for a region may be provided (**901**). Network measurement data from transmitters may be observed and collected including a signal characteristic from each of the transmitters (operation **903**). An average value for the signal characteristic among the transmitters may be determined (operation **905**). The average for the signal characteristic may be a weighted average. The observed network measurement data may be modified using the determined average value (operation **907**) and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **909**).

FIG. **10** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of previously-gathered outdoor calibration data for a predetermined region in a wireless network may be provided (operation **1001**). Network measurement data may be observed and collected (operation **1003**). The network measurement data may be compared with the database of calibration data to thereby determine a plurality of location estimates for the mobile station (operation **1005**). The location estimates may be derived using modified, unmodified, limited signal characteristics, several signal characteristics, etc. For each location estimate, a confidence measure may be determined (operation **1007**). A location may be determined based on the plurality of location estimates and their respective confidence measures (**1009**). For example, the location may be determined based on a weighted average, where the weights are directly proportional to the confidence measures.

The embodiments described above may be used in communication devices, such as, a base station, having varying configurations that include, but are not limited to: predetermined calibration data collected over varying terrain, different base station configurations, varying cellular communication protocols, etc.

While preferred embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalents, many variations and modifications naturally occurring to those skilled in the art from a perusal hereof.

What is claimed is:

**1**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network;

collecting observed network measurement data;

modifying said observed network measurement data; and

comparing said modified network measurement data with said database of calibration data by positioning determining equipment to thereby determine the location of the mobile station.

**2**. The method of claim **1** wherein said database comprises previously-gathered calibration data at one or more predetermined calibration points within said region.

**3**. The method of claim **2** wherein said previously-gathered calibration data at one or more predetermined calibration points is combined to form previously-gathered calibration data for one or more non-uniform grid points within said region.

**4**. The method of claim **1** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**5**. The method of claim **1** wherein said observed network measurement data includes data collected at the mobile station.

**6**. The method of claim **1** wherein said previously-gathered calibration data includes signal strength information measured at a predetermined calibration point within said region for a signal transmitted from a known location within or in proximity to said region.

**7**. The method of claim **1** wherein said previously-gathered calibration data includes signal strength information measured by a receiver at a known location within or in proximity to said region for a signal transmitted from a predetermined calibration point within said region.

**8**. The method of claim **1** wherein said previously-gathered calibration data includes round trip time information for signals traveling between a predetermined calibration point within said region and a known location within or in proximity to said region.

**9**. The method of claim **1** wherein said previously-gathered calibration data includes time difference of arrival information for a first signal traveling between a first known location and a predetermined calibration point within said region and a second signal traveling between a second known location and said calibration point.

**10**. The method of claim **1** wherein said previously-gathered calibration data includes information identifying a serving cell of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**11**. The method of claim **1** wherein said previously-gathered calibration data includes information identifying a serving sector of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**12**. The method of claim **1** wherein said previously-gathered calibration data includes information regarding a state of said wireless network.

**13**. The method of claim **1** wherein said previously-gathered calibration data includes calibration data gathered at a

predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**14**. The method of claim **13** wherein said observed network measurement data is collected at a mobile station located within a structure.

**15**. A system for determining a location of a mobile station, comprising:

a database of previously-gathered calibration data for a predetermined region in a wireless network;

circuitry for collecting observed network measurement data;

circuitry for modifying said observed network measurement data; and

circuitry for comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**16**. The system of claim **15** wherein said database comprises previously-gathered calibration data at one or more predetermined calibration points within said region.

**17**. The system of claim **16** further comprising circuitry for combining said previously-gathered calibration data at one or more predetermined calibration points to thereby form previously-gathered calibration data for one or more non-uniform grid points within said region.

**18**. The system of claim **15** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**19**. The system of claim **15** wherein said mobile station includes said circuitry for collecting observed network measurement data.

**20**. The system of claim **15** further comprising circuitry for measuring signal strength at a predetermined calibration point within said region for a signal transmitted from a known location within or in proximity to said region.

**21**. The system of claim **15** further comprising circuitry for measuring signal strength at a receiver at a known location within or in proximity to said region for a signal transmitted from a predetermined calibration point within said region.

**22**. The system of claim **15** further comprising circuitry for determining round trip time for signals traveling between a predetermined calibration point within said region and a known location within or in proximity to said region.

**23**. The system of claim **15** further comprising circuitry for determining time difference of arrival for a first signal traveling between a first known location and a predetermined calibration point within said region and a second signal traveling between a second known location and said calibration point.

**24**. The system of claim **15** further comprising circuitry for identifying a serving cell of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**25**. The system of claim **15** further comprising circuitry for identifying a serving sector of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**26**. The system of claim **15** wherein said previously-gathered calibration data includes information regarding a state of said wireless network.

**27**. The system of claim **15** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**28**. The system of claim **27** wherein said observed network measurement data is collected at a mobile station located within a structure.

**29**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a serving transmitter;

collecting observed network measurement data including a first signal characteristic from said serving transmitter;

modifying said observed network measurement data using said first signal characteristic; and

comparing said modified network measurement data with said database of calibration data by positioning determining equipment to thereby determine the location of the mobile station.

**30**. The method of claim **29** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**31**. The method of claim **29** wherein said observed network measurement data includes data collected at the mobile station.

**32**. The method of claim **29** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**33**. The method of claim **32** wherein said observed network measurement data is collected at a mobile station located within a structure.

**34**. The method of claim **29** wherein said first signal characteristic is signal strength.

**35**. The method of claim **34** wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.

**36**. The method of claim **35** wherein the modifying of said calibration data uses a difference between said first and second signal characteristics.

**37**. The method of claim **29** wherein said first signal characteristic is signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.

**38**. The method of claim **37** wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.

**39**. The method of claim **29** wherein said observed network measurement data includes a data set comprising:

$[P_1, \ldots P_n, TA]$

where:

$P_1$ represents the signal strength of said serving transmitter as measured at said mobile station,

$P_n$ represents a signal strength of at a $n^{th}$ neighboring transmitter as measured at said mobile station, and

TA represents a timing advance parameter;

and wherein said modified network measurement data includes a data set comprising:

$[0, \ldots P_1\text{-}P_{n-1}, P_1\text{-}P_n, TA]$

where:

0 represents a difference between $P_1$ and $P_1$,

$P_1\text{-}P_{n-1}$ represents a difference between $P_1$ and $P_{n-1}$, and

$P_1\text{-}P_n$ represents a difference between $P_1$ and $P_n$.

**40**. The method of claim **39** wherein said first neighboring transmitter is not a member of said wireless network.

**41**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network;

collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters;

determining an average value for select ones of said signal characteristics;

modifying said observed network measurement data using said average value; and

comparing said modified network measurement data with said database of calibration data by positioning determining equipment to thereby determine the location of the mobile station.

**42**. The method of claim **41** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**43**. The method of claim **41** wherein said observed network measurement data includes data collected at the mobile station.

**44**. The method of claim **41** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**45**. The method of claim **41** wherein said observed network measurement data is collected at a mobile station located within a structure.

**46**. The method of claim **41** wherein said signal characteristic is signal strength.

**47**. The method of claim **46** wherein the modifying of said calibration data uses a difference between said average value and said signal characteristic for a first one of said plural transmitters.

**48**. The method of claim **41** wherein said signal characteristic is signal strength of a control channel.

**49**. The method of claim **41**, wherein the observed network measurement data includes received signal strength of said transmitters as said mobile station.

**50**. The method of claim **41** wherein said observed network measurement data includes a data set comprising:

$[P_1, P_2, P_3, TA]$

where:

$P_1$ represents the signal strength of a first one of said plural transmitters as measured at said mobile station,

$P_2$ represents a signal strength of a second one of said plural transmitters as measured at said mobile station wherein $P_2>P_1$,

$P_3$ represents a signal strength of a third one of said plural transmitters as measured at said mobile station wherein $P_2>P_3$, and

TA represents a timing advance parameter;

and wherein said modified network measurement data includes a data set comprising:

$[P_1-P_{AVG}, P_2-P_{AVG}, P_3-P_{AVG}, TA]$

where:

$P_{AVG}$ represents an average value of $P_1$, $P_2$, and $P_3$,

$P_1-P_{AVG}$ represents a difference between $P_1$ and $P_{AVG}$,

$P_2-P_{AVG}$ represents a difference between $P_2$ and $P_{AVG}$,

$P_3-P_{AVG}$ represents a difference between $P_3$ and $P_{AVG}$.

**51**. The method of claim **50** wherein said first transmitter is a serving transmitter for said mobile station and said second and third transmitters are neighboring transmitters.

**52**. The method of claim **41** wherein at least one of said plurality of transmitters is not a member of said wireless network.

* * * * *

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(12) **United States Patent**
**Alles et al.**

(10) **Patent No.: US 8,786,494 B2**
(45) **Date of Patent: *Jul. 22, 2014**

(54) **METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT**

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(73) Assignee: **Andrew LLC**, Hickory, NC (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/771,542**

(22) Filed: **Feb. 20, 2013**

(65) **Prior Publication Data**

US 2013/0165145 A1 Jun. 27, 2013

**Related U.S. Application Data**

(63) Continuation of application No. 12/424,320, filed on Apr. 15, 2009, now Pat. No. 8,400,358, and a continuation of application No. 12/026,333, filed on Feb. 5, 2008, now Pat. No. 7,561,104.

(60) Provisional application No. 60/899,379, filed on Feb. 5, 2007.

(51) **Int. Cl.**

| | |
|---|---|
| ***G01S 3/02*** | (2006.01) |
| ***G01S 5/02*** | (2010.01) |
| ***H04W 4/02*** | (2009.01) |

(52) **U.S. Cl.**

CPC ..... ***G01S 5/0252*** (2013.01); ***G01S 5/021*** (2013.01); ***G01S 5/0257*** (2013.01); ***H04W 4/02*** (2013.01)

USPC ..... **342/451**; 342/457

(58) **Field of Classification Search**

CPC ..... G01S 5/06; G01S 5/0242; G01S 5/0252; H04W 64/00

USPC ..... 342/451, 457, 463–465; 455/456.1, 455/456.6, 457

See application file for complete search history.

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| | | | | |
|---|---|---|---|---|
| 7,561,104 | B2 * | 7/2009 | Alles et al. | 342/451 |
| 8,400,358 | B2 * | 3/2013 | Alles et al. | 342/451 |

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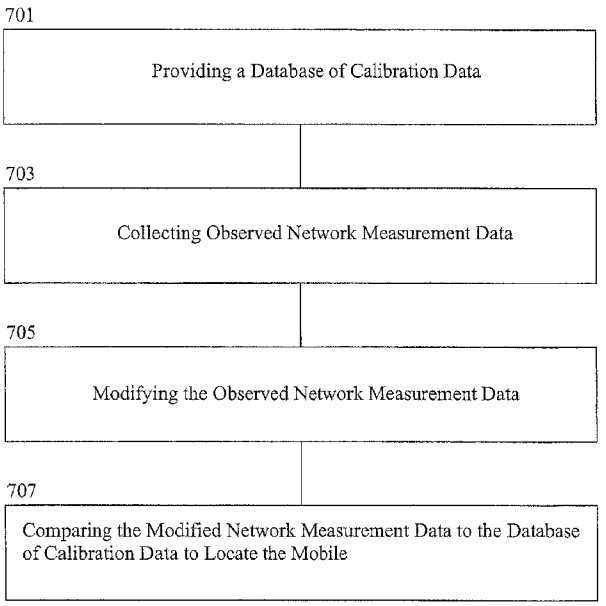
*Primary Examiner* — Dao Phan

(74) *Attorney, Agent, or Firm* — Duane Morris LLP

(57) **ABSTRACT**

A method of modifying calibration data used to geo-locate a mobile station located in an indoor environment is disclosed. When a mobile station is located indoors, the signal strength of signals received and/or transmitted by the mobile station have the tendency to be lower than the strength of the signals received by a mobile station located outdoors. As a result of these lower signal strengths, geo-location efforts which rely on signal strengths may result in unsatisfactory location accuracy. Modifying pre-existing calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics.

**35 Claims, 10 Drawing Sheets**



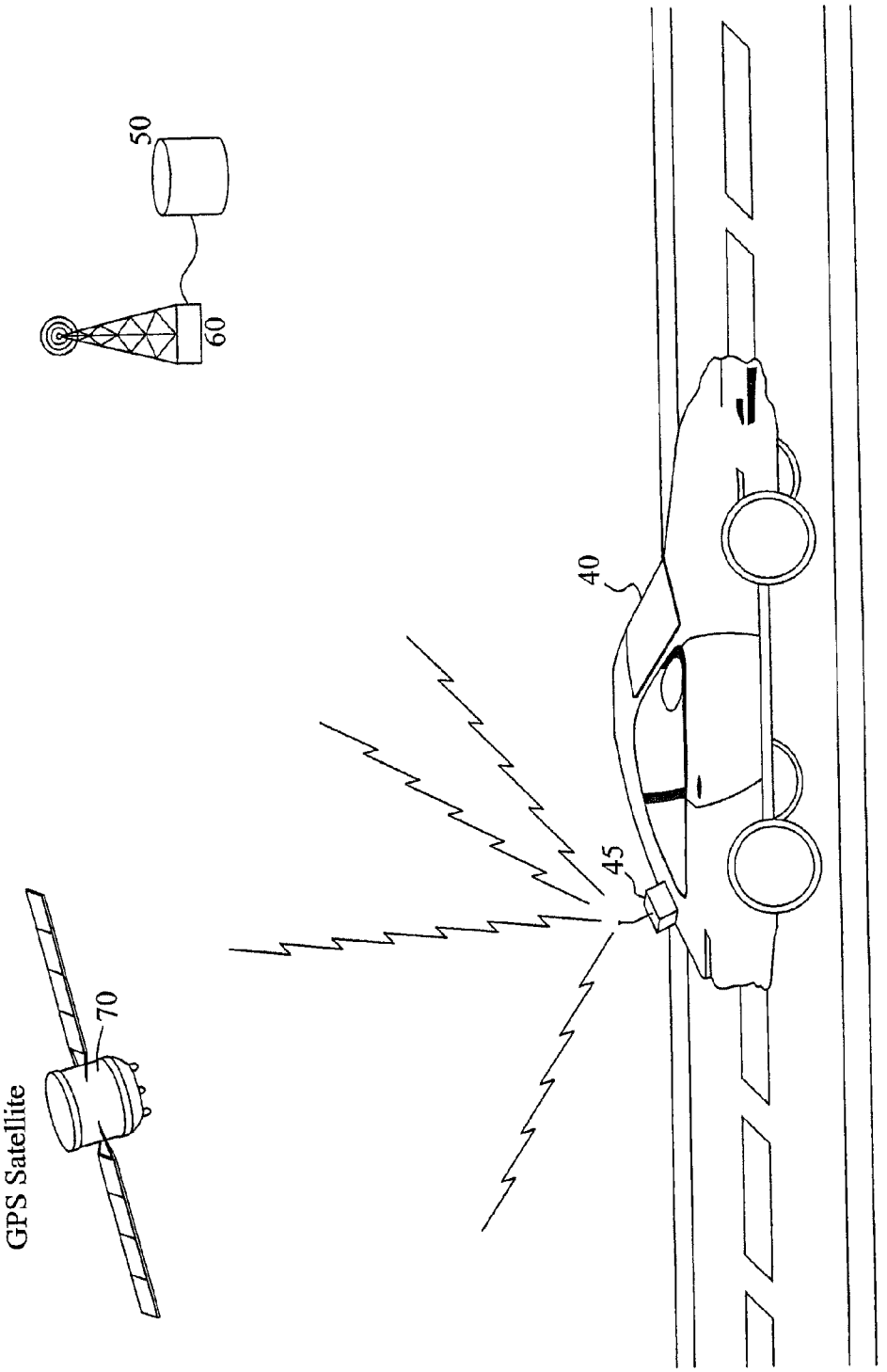



Figure 1

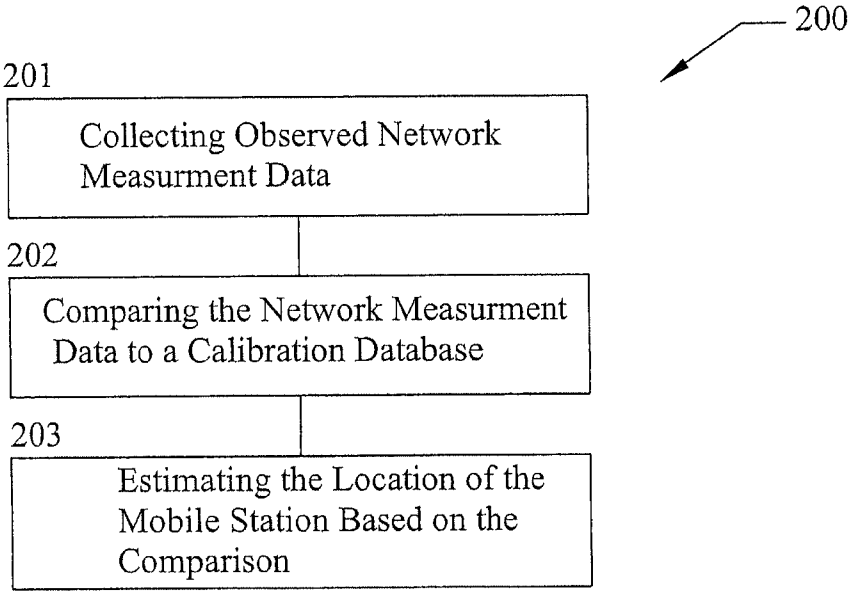

200
201
Collecting Observed Network Measurment Data
202
Comparing the Network Measurment Data to a Calibration Database
203
Estimating the Location of the Mobile Station Based on the Comparison

Figure 2

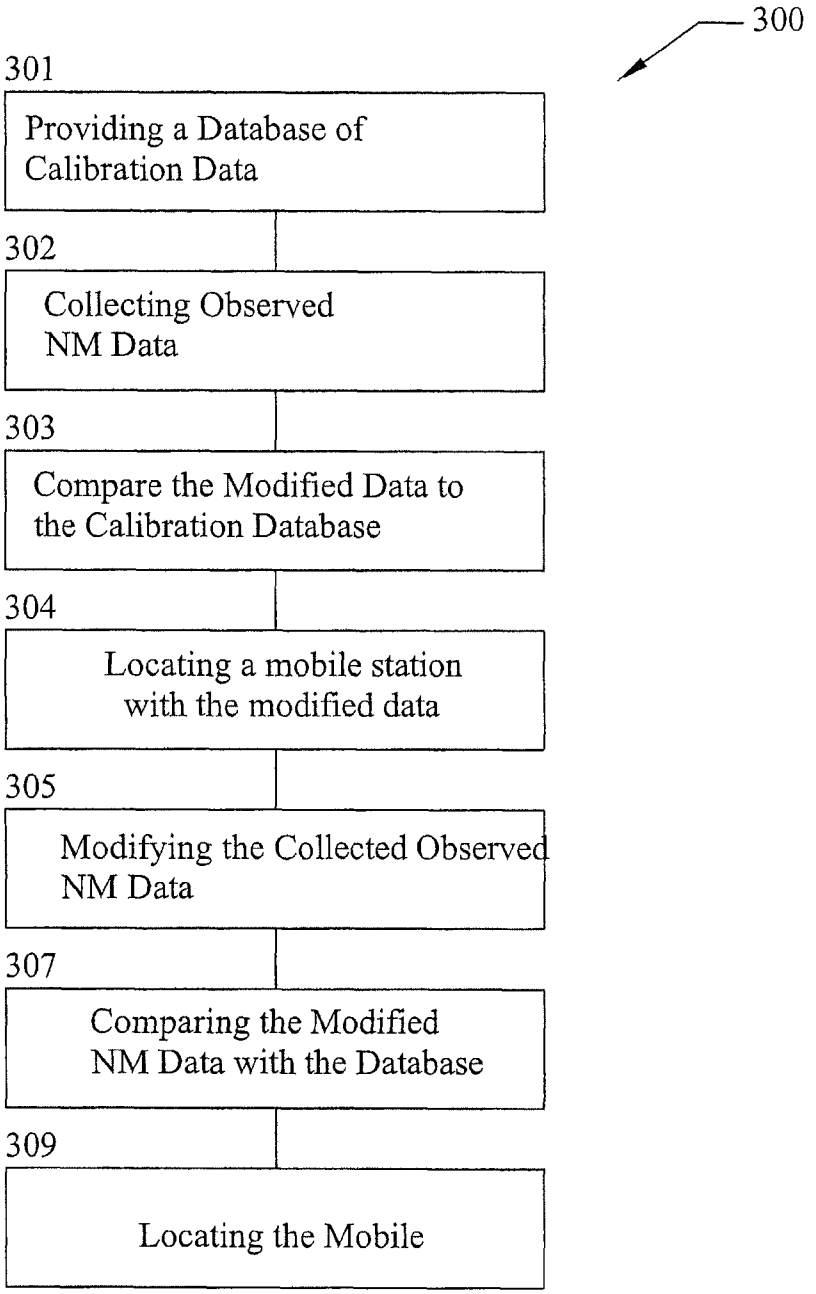

300
301
Providing a Database of Calibration Data
302
Collecting Observed NM Data
303
Compare the Modified Data to the Calibration Database
304
Locating a mobile station with the modified data
305
Modifying the Collected Observed NM Data
307
Comparing the Modified NM Data with the Database
309
Locating the Mobile

Figure 3

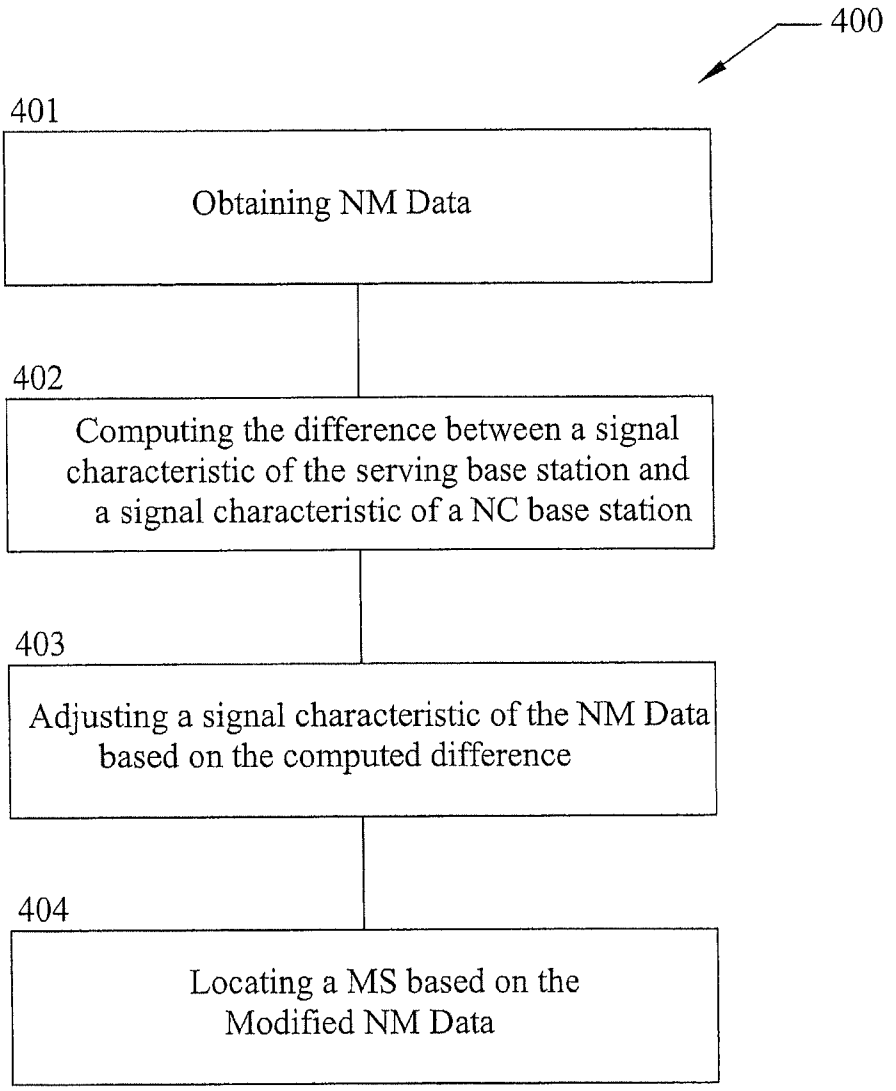

400
401
Obtaining NM Data
402
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station
403
Adjusting a signal characteristic of the NM Data based on the computed difference
404
Locating a MS based on the Modified NM Data

Figure 4

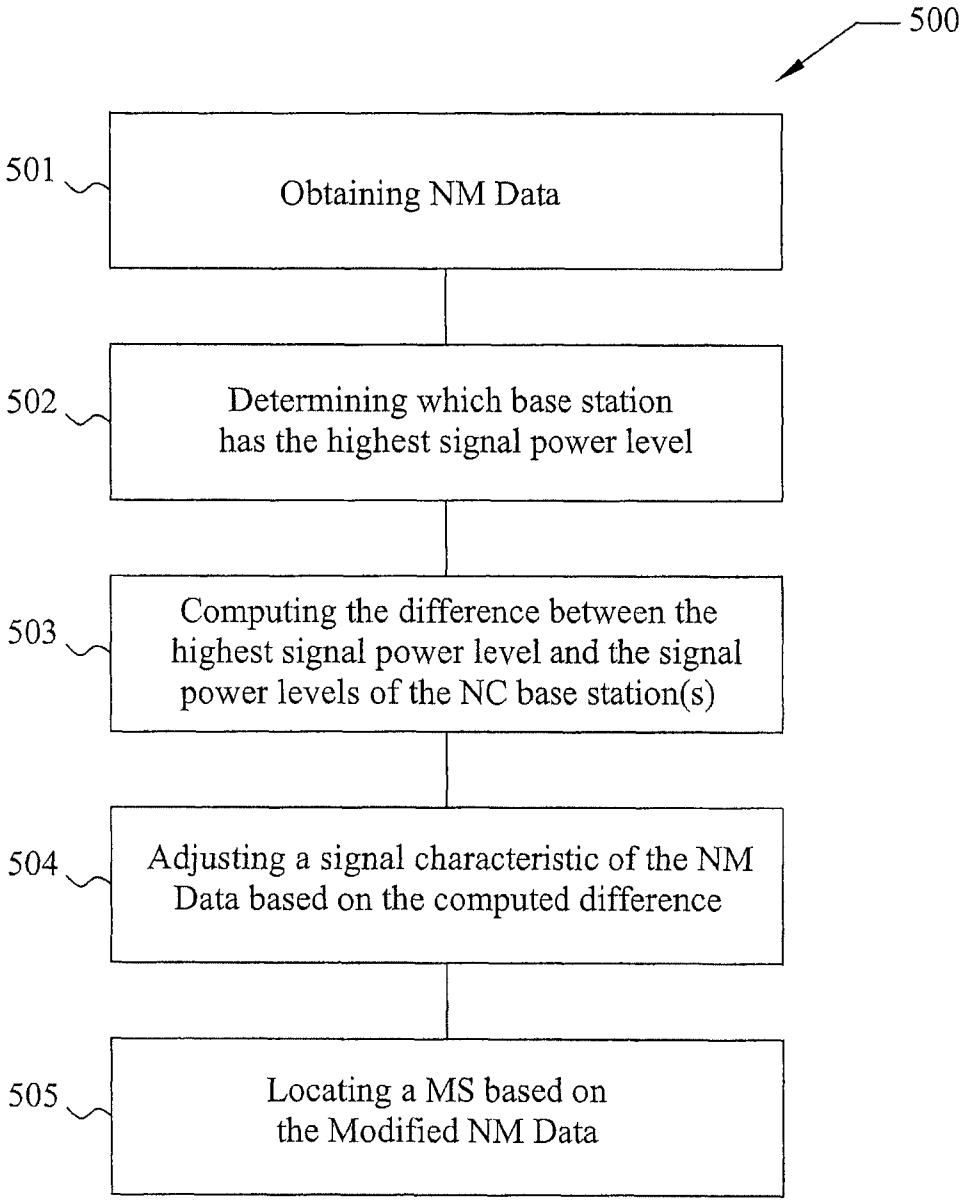

500
501
Obtaining NM Data
502
Determining which base station has the highest signal power level
503
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
504
Adjusting a signal characteristic of the NM Data based on the computed difference
505
Locating a MS based on the Modified NM Data

Figure 5

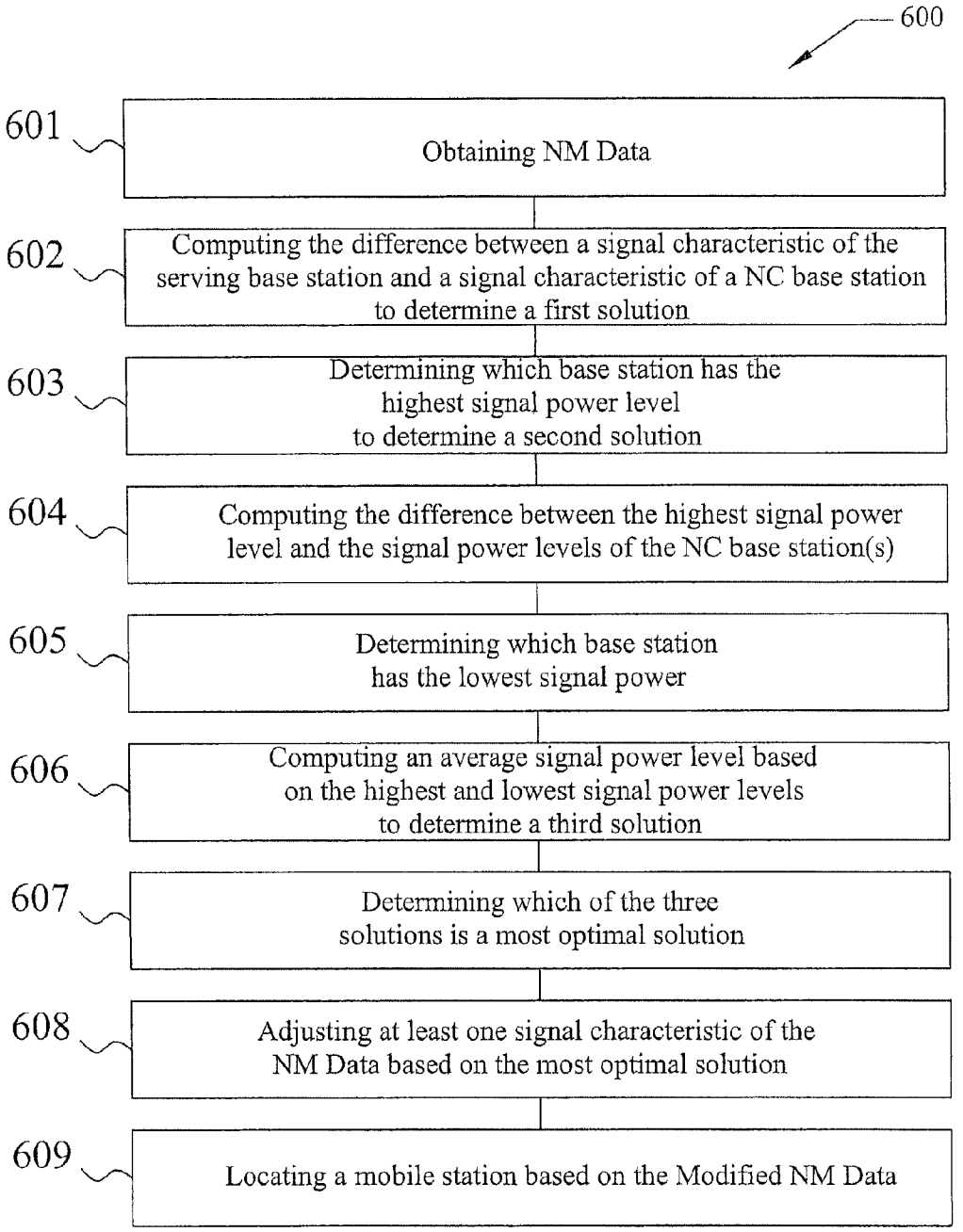

600
601
Obtaining NM Data
602
Computing the difference between a signal characteristic of the serving base station and a signal characteristic of a NC base station to determine a first solution
603
Determining which base station has the highest signal power level to determine a second solution
604
Computing the difference between the highest signal power level and the signal power levels of the NC base station(s)
605
Determining which base station has the lowest signal power
606
Computing an average signal power level based on the highest and lowest signal power levels to determine a third solution
607
Determining which of the three solutions is a most optimal solution
608
Adjusting at least one signal characteristic of the NM Data based on the most optimal solution
609
Locating a mobile station based on the Modified NM Data

Figure 6

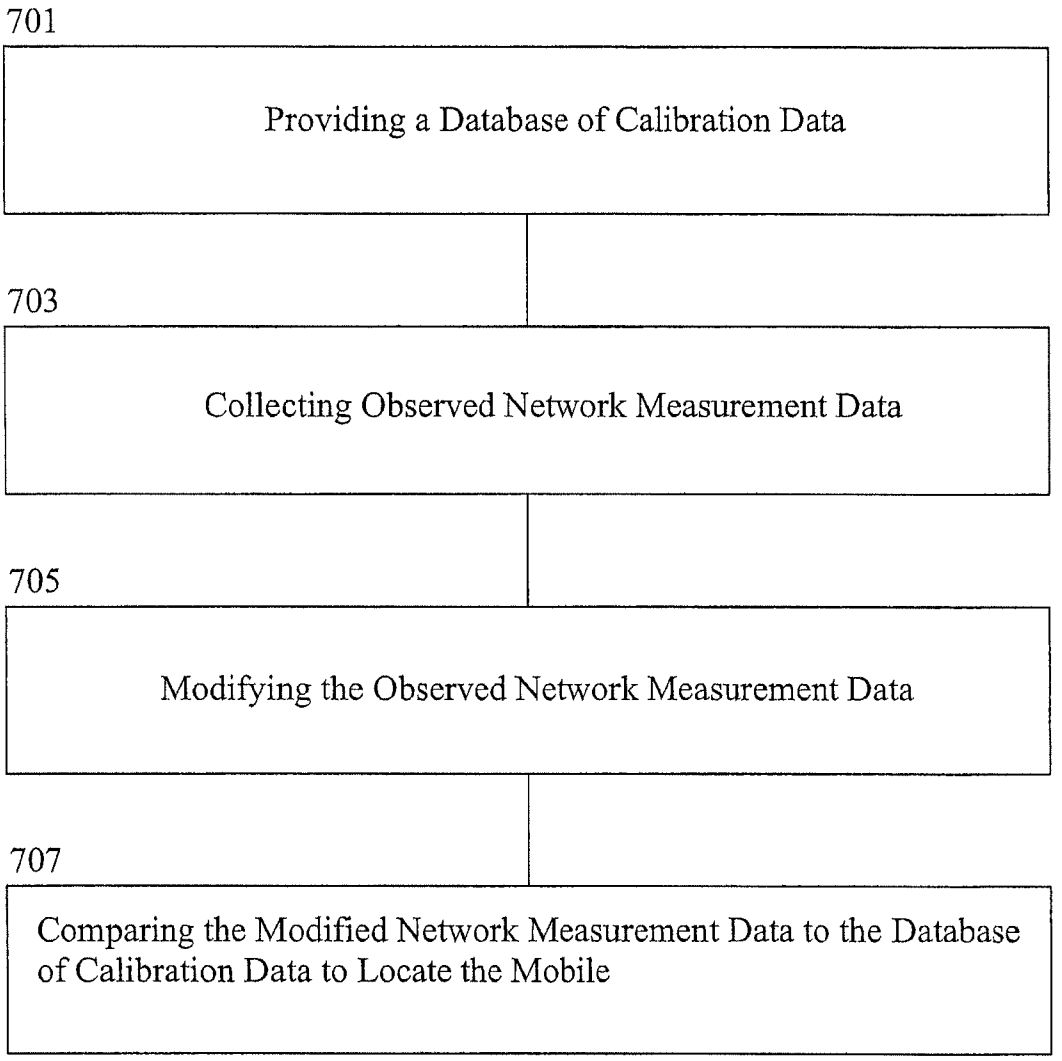

701
Providing a Database of Calibration Data
703
Collecting Observed Network Measurement Data
705
Modifying the Observed Network Measurement Data
707
Comparing the Modified Network Measurement Data to the Database of Calibration Data to Locate the Mobile

Figure 7

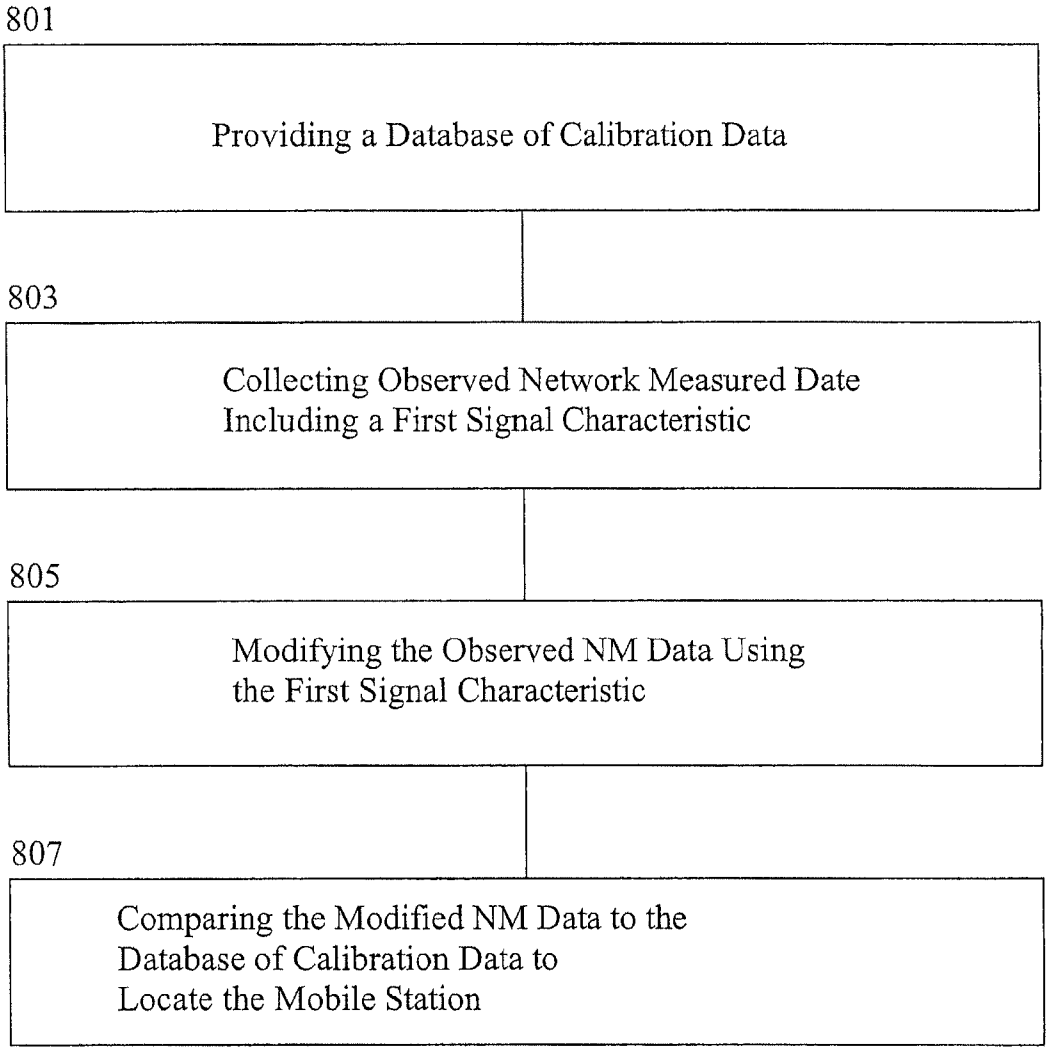

801
Providing a Database of Calibration Data
803
Collecting Observed Network Measured Date Including a First Signal Characteristic
805
Modifying the Observed NM Data Using the First Signal Characteristic
807
Comparing the Modified NM Data to the Database of Calibration Data to Locate the Mobile Station

Figure 8

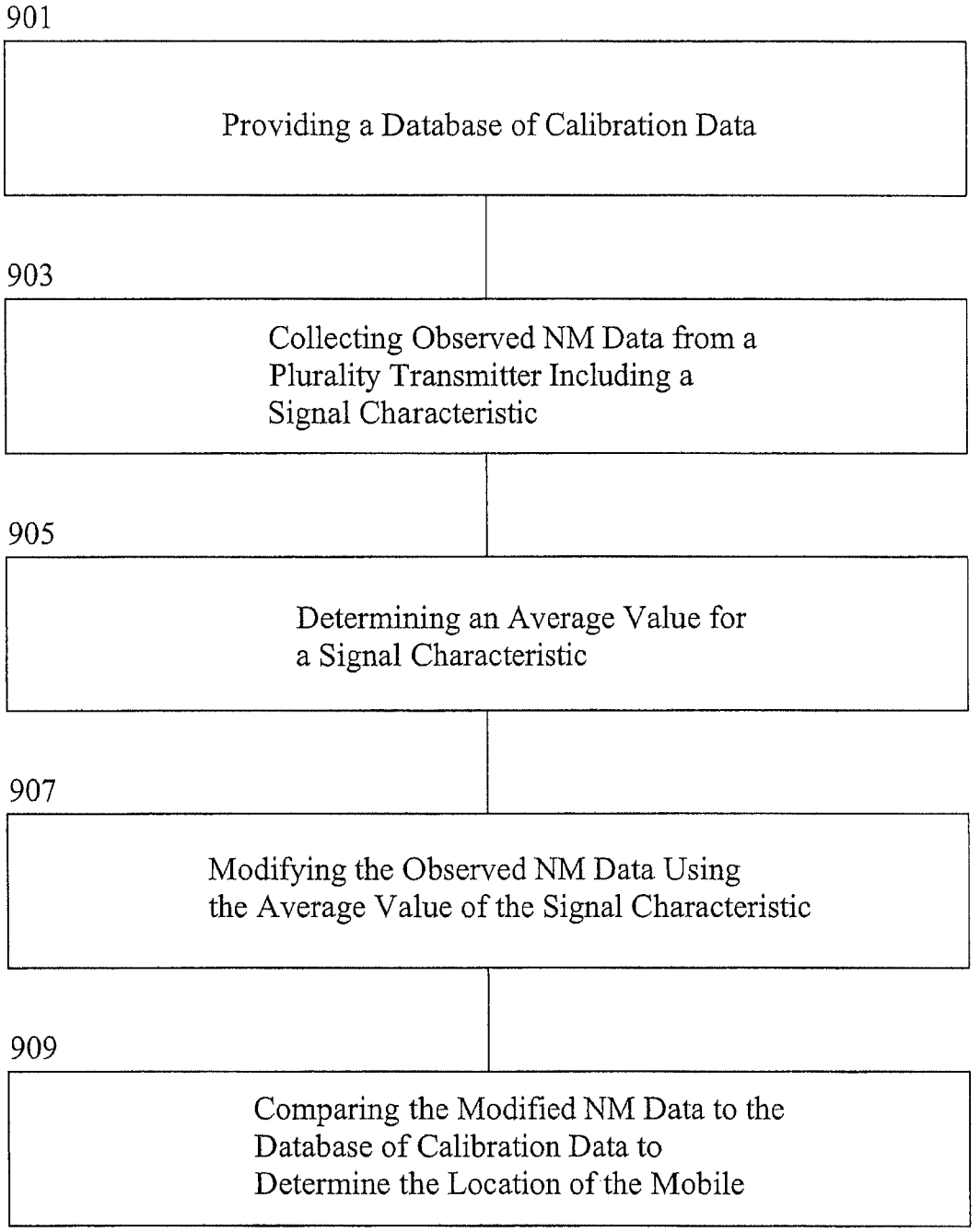

901
Providing a Database of Calibration Data
903
Collecting Observed NM Data from a Plurality Transmitter Including a Signal Characteristic
905
Determining an Average Value for a Signal Characteristic
907
Modifying the Observed NM Data Using the Average Value of the Signal Characteristic
909
Comparing the Modified NM Data to the Database of Calibration Data to Determine the Location of the Mobile

Figure 9

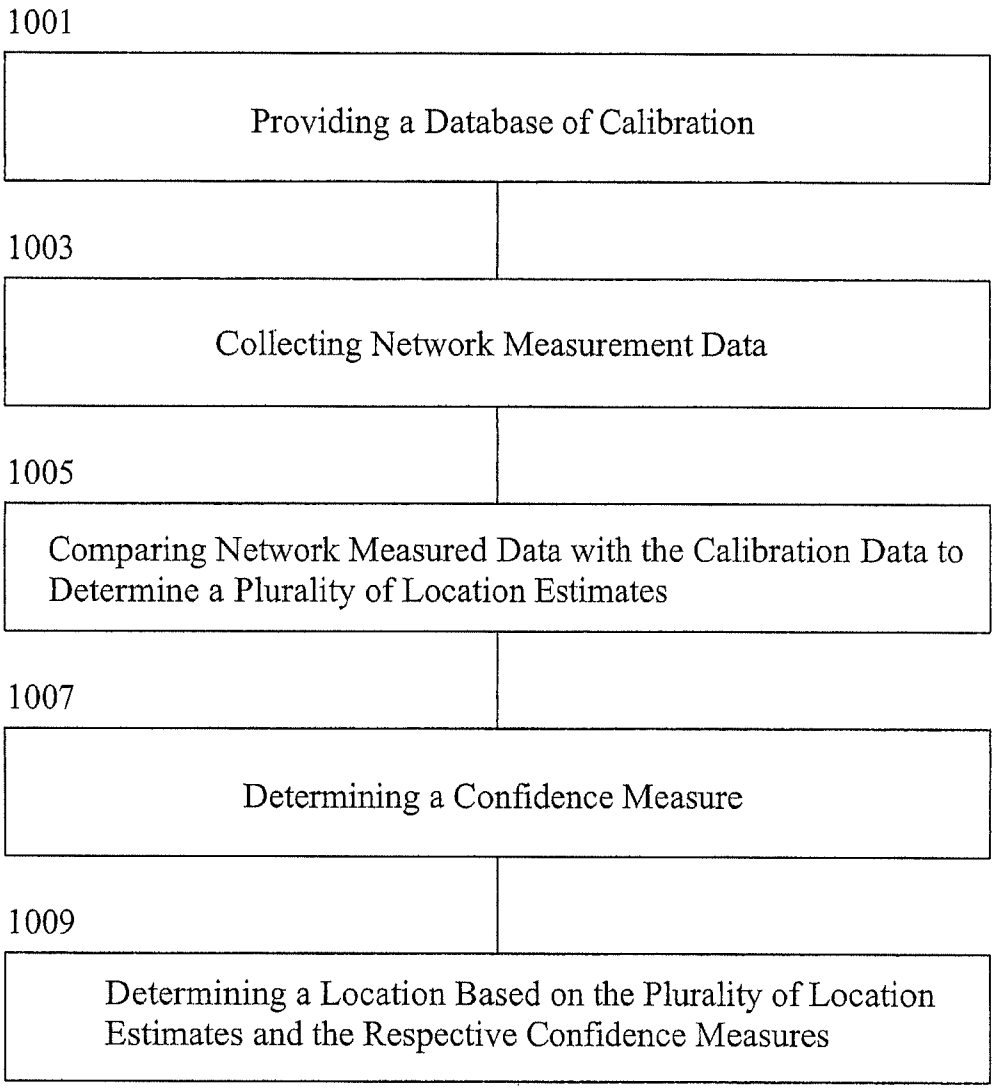

1001
Providing a Database of Calibration
1003
Collecting Network Measurement Data
1005
Comparing Network Measured Data with the Calibration Data to Determine a Plurality of Location Estimates
1007
Determining a Confidence Measure
1009
Determining a Location Based on the Plurality of Location Estimates and the Respective Confidence Measures

Figure 10

# METHOD TO MODIFY CALIBRATION DATA USED TO LOCATE A MOBILE UNIT

## CROSS REFERENCES

The present application is a continuation application of and claims the priority benefit of co-pending U.S. application Ser. No. 12/424,320 entitled "Method to Modify Calibration Data Used to Locate a Mobile Unit," which is related to and claims the priority benefit of co-pending U.S. application Ser. No. 12/026,333 entitled "Method to Modify Calibration data Used to Locate a Mobile Unit," which is related to and claims the priority benefit of provisional application No. 60/899,379 entitled "Mobile Location Using Network Measurement Reports" filed on Feb. 5, 2007, each of which are hereby incorporated by reference in their entirety.

## BACKGROUND

The use of wireless communication devices such as telephones, pagers, personal digital assistants, laptop computers, etc., hereinafter referred to collectively as "mobile appliances" or "mobiles stations" has become prevalent in today's society. In recent years, at the urging of public safety groups, there has been increased interest in technology which can determine the geographic position or "geo-locate" a mobile station in certain circumstances.

Estimating the location or "geo-locating" a mobile station may require one or more types of calibration data associated with the mobile station (e.g., signal strength, round trip time, time difference of arrival (TDOA), etc.). Calibration data is typically collected in an outdoor environment. The primary reason for collecting calibration data outdoors is the greater ease of performing automated calibration collection procedures or, in some instances, manual collection procedures along roads. It is more time-consuming to perform calibration procedures indoors due to the required access to buildings and the inability to utilize automated collection procedures designed for outdoor environments.

When a wireless device is located indoors, the signal strengths of signals received from the serving and/or neighboring base stations tend to be lower than the strength of the signals received by a wireless device located outdoors. As a result of these lower signal strengths, performing comparisons between the received signal strengths of the indoor wireless device and signal strength data stored in a calibration database may result in a poor estimated location accuracy. Modifying the calibration data obtained outdoors may provide a way to simulate indoor calibration data characteristics. Calibration data collected in areas located adjacent to indoor facilities may be altered to increase the accuracy of location estimates of a mobile station located indoors.

One embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network and collecting observed network measurement data. The method also includes modifying the observed network measurements and then comparing the modified data with the database of calibration data to determine the location of the mobile station.

Another embodiment of the present subject matter is a system for determining a location of a mobile station. The system includes a database of previously-gathered calibration data for a region in a wireless network and circuitry such as a wireless receiver for collecting observed network measurement data. The system includes circuitry, such as a processor, for modifying the observed network measurement data; and circuitry, such as a processor, for comparing the modified data with the calibration data in the database to determine the location of the mobile station.



Yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network which includes a serving transmitter. The method collects observed network measurement data including a first network characteristic from said serving transmitter and modifies the observed network measurement data using said first characteristic. The method compares the modified network measurement data with the database of calibration data to thereby determine the location of the mobile station.

Still yet another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network including a first transmitter and a second transmitter. The method also includes collecting observed network measurement data including a first and second signal characteristic from the first and second transmitters respectively and determining which of the first and second signal characteristics has a greater magnitude. The observed network measurement data may be modified using the greater magnitude signal characteristic, and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station.

A further embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered calibration data for a region in a wireless network and collecting observed network measurement data from a plurality of transmitters which includes a signal characteristic from each one of said plural transmitters. The method also includes determining an average value for the signal characteristics and modifying the observed network measurement data using the average value. The method may then compare the modified network measurement data with the database of calibration data to determine the location of the mobile station.

Still a further embodiment of the present subject matter recognizes that it may be desirable to locate a mobile station by obtaining at least one network measurement report representing at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of neighboring base stations. The method may also compute the difference between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the neighboring base stations to determine a first solution and determine which neighboring base station has the highest signal power level at a particular location. The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be computed to determine a second solution. It may also be determined which neighboring base station has the lowest signal power level at the particular location. The method may also comprise computing an average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level to determine a third solution and determining which of the three solutions is a most optimal solution based on at least one comparison of the three solutions. At least one signal characteristic of the network measurement report may be

adjusted based on the most optimal solution and the modified network measurement report may be utilized to locate a mobile station.

Another embodiment of the present subject matter is a method for determining a location of a mobile station. The method includes providing a database of previously-gathered outdoor calibration data for a region in a wireless network, collecting network measurement data, and comparing the network measurement data with the database of calibration data to thereby determine several location estimates of the mobile station. The method may also include determining a confidence measure for each of the plurality of location estimates and determining the location of the mobile station based on the plurality of location estimates and their respective confidence measures.

These and other advantages of the disclosed subject matter over the prior art will be readily apparent to one skilled in the art to which the disclosure pertains from a perusal of the claims, the appended drawings, and the following detailed description of the preferred embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a wireless communications networking environment.

FIG. **2** illustrates a flow diagram of an exemplary inventive concept.

FIG. **3** illustrates a flow diagram of another exemplary inventive concept.

FIG. **4** illustrates a flow diagram of yet another exemplary inventive concept.

FIG. **5** illustrates a flow diagram of still another exemplary inventive concept.

FIG. **6** illustrates a flow diagram of still yet another exemplary inventive concept.

FIG. **7** illustrates a flow diagram of an embodiment of the subject matter.

FIG. **8** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **9** illustrates a flow diagram of another embodiment of the subject matter.

FIG. **10** illustrates a flow diagram of another embodiment of the subject matter.

## DETAILED DESCRIPTION

Calibration data samples obtained outdoors may be used to simulate indoor calibration data to locate a mobile station (MS) in an indoor facility. A method of utilizing calibration data samples to represent indoor and/or outdoor wireless networking environments is described herein.

Reliably locating a mobile station located indoors, even when the calibration data has been obtained in an outdoor environment, may simplify a calibration collection procedure. Calibration data obtained outdoors may be modified and substituted for indoor calibration data. In addition network measurement data may be modified for comparison with the outdoor calibration data.

In general, a non-uniform grid point (NUG) may represent the signal characteristics and/or calibration data over a given region. As illustrated in FIG. **1**, a set of NUGs (NUG**1**, NUG**2** and NUG**3**) are shown as being a part of a larger geographical region (R), which includes various wireless networking components (e.g., (MS **11** and BS **20**-NUG**1**), (MSs **12**-**15**-NUG**2**) and (MSs **16**-**18** and BS **30**-NUG**3**)). The NUGs represent an area of collected calibration data, which may be stored in a database for easy retrieval during a calibration data comparison operation between the NUG and a received network measurement report (NMR).

Calibration data may be obtained from data collection devices during field test operations, and/or from MSs or other communication devices within the general area of the NUG. Cross-NUG communications may occur between MSs and/or BSs located within communication range of one or more of the NUGs. For example, BS **10** may be located outside the region (R) and may communicate with one or more devices located in the various NUGs **1**-**3**. The different NUGs **1**-**3** may be separately defined by a variety of parameters. For example, geographical areas (e.g., mountains, buildings, roads) may be a factor in deciding the boundaries of a NUG. Additionally, varying concentrations of MSs may be another factor that separates one NUG from another.

Network measurement reports (NMRs) may be used to represent network characteristics at particular locations within a given region (R). Any point located within a NUG may have corresponding signal strength levels that represent the signal power of the serving and/or neighboring cell (NC) BSs. An exemplary NMR may be represented by example_data_vector=[P**1**, P**2**, P**3**, TA**1**]. Referring to FIG. **1**, the power level signals (P**1**-P**3**) may represent the power levels of the three BSs **10**, **20** and **30**, as measured at a particular location. The timing advance parameter TA**1** (or equivalent parameter) may be used to represent timing information of signals transmitted between the MS and one or more BSs.

The value of the timing advance (TA) parameter corresponds to the length of time a signal from a MS takes to reach a particular BS. A MS may be configured to transmit data signals at specific timeslot intervals depending on the type of wireless communication protocol employed (e.g., TDMA, GSM, 3GPP etc.). Using the speed of light (c=3*10^8 m/s) as a reference velocity for the radio waves, the TA parameter may be increased or decreased depending on the distance between the MS and the BS. The TA parameter may be periodically adjusted as the distance from the MS to the BS changes. Of course, a NMR may contain any number and type of parameters, and may be used to estimate the location of a MS.

For example, NMR(s) may be transmitted from the MS or from other wireless communication components to position determining equipment (PDE) **50**, which processes the received NMR information and may attempt to locate the position of the MS. NMR(s) may be periodically generated by MSs or other communication devices to calibrate the NUG. The NUG may also be based entirely on information received from NMR(s) generated by MSs located in the NUG.

The received Network Measurement data (NM data) may be compared to predetermined calibration data representing one or more NUGs to estimate the location of a MS. In a case where NM data is compared against a NUG, like parameters may be compared to estimate if the target MS **18** is within the NUG. Similarly, NUG parameters may be computed in response to a comparison operation, and then compared to the NM data. Each NUG may have a series of parameters and/or functions characterizing one or more particular locations in the NUG. Given a received set of one or more NMR(s) obtained from some unknown location, an estimate of that unknown location may be calculated using the characterization of the NUG or uniform grid (UG) over that region.

It may be desirable to use the original unmodified NM data directly without modification when locating a mobile station. Assuming the MS is located in an indoor facility, the data contained in the NMR(s) may be a function of calibration data collected outdoors. In some cases, the unmodified outdoor calibration data used to represent the indoor facility may

provide an accurate representation of the location of the target MS **18** (e.g., low distortion structures, open-faced facilities, etc.).

Referring to FIG. **1**, the NM data may be sent from the target MS **18** to the BS **10**, where the PDE **50** processes the NMR and performs one or more comparison operations between the NM data and the calibration data of the NUG(s). Once the comparison operation is complete, the location of the target MS **18** may be estimated. A direct comparison of the original NM data may be made against the corresponding NUG(s) characteristics. Alternatively, the NM data may not be modified even if NUG(s) are utilized to estimate the location of the mobile station.

NM data may also be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations. For example, differences in parameters between the serving cell and the NC may be calculated and the quantities used to modify the original NM data.

If an original NMR received at the PDE **50** had the form NMR**1**=[P**1**, P**2**, P**3**, TA**1**], where P**1** is the serving BS power at a particular location, P**2** is a first NC power, P**3** is a second NC power, and TA**1** is the timing advance parameter, the modified NMR may be represented by: NMR_modified=[**0**, P**1**-P**2**, P**1**-P**3**, TA**1**]. The resulting data vector may be used to calculate new relative power levels of the NC BSs by subtracting or adding the NMR_modified parameters from the original NMR**1** parameters. In this example, the power of the serving BS may be used as a basis to obtain relative power level modification parameters to modify the NC power level parameters of NMR(s).

The calculated modified parameters (NMR_modified=[**0**, P**1**-P**2**, P**1**-P**3**, TA**1**]) may also be used to simulate an indoor facility by modifying NMR(s) received from an indoor location. Alternatively, the modified parameters may be used to conduct other calculations to obtain a desired set of modified results. For example, the modified NMR may be compared to one or more of the NUG(s) to provide an estimated location of a MS. Of course, the serving BS power level is not a required parameter to be used as a basis to obtain relative power level modification parameters, and many other parameters may be used to modify the NM data to simulate an indoor facility.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevServing_WD represents the received signal strength of the serving base station's control channel measured by the wireless device at an unknown location. Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel, RxLevServing_DB represent the average received signal strength of the serving station's control channel, stored in a database of the PDE **50** during the calibration process, and RxLevNeigh_i_DB represent the average received signal strength of the $i^{th}$ neighbor's control channel stored in the database during a calibration process (i=1 to N, where N is the number of neighbor cells reported).

A comparison operation may be conducted between the received signal strengths of the NC-BSs relative to the serving BS's received signal strength. For example, a comparison may include computing the difference between the parameters of the serving base station and the $i^{th}$ neighbor's parameters (i.e., (RxLevServing_WD−RxLevNeigh_i_WD) and (RxLevServing_DB−RxLevNeigh_i_DB)). Once the differences are calculated, the magnitudes of the differences may be compared to a predetermined threshold value used to distinguish between an acceptable difference value requiring no modification to the NM data and a non-acceptable difference value invoking further modification efforts.

NM data may be modified by an amount relative to the signal strength of a NC-BS. In this example, the NC-BS having the highest signal power may be used as a basis to modify the values of the NM data. The differences between the NC having the highest cell power and the cell powers of the remaining NC-BSs may be calculated and the quantities thereof used to modify the original NM data.

An exemplary NMR may have the form NMR=[P**1**, P**2**, P**3**, P**4**, TA**1**], where P**1** is the serving BS signal power, P**2** is a NC having the highest signal power at the intended location of the NMR, P**3** and P**4** are different NC signal powers, and TA**1** is a timing advance parameter. In this example, P**2** has the highest signal power level and may be used as the basis for modifying the parameters of the NMR. The modified NMR may then be represented by NMR_modified**2**=[P**2**-P**1**, **0**, P**2**-P**3**, P**2**-P**4**, TA**1**]. The resulting data vector NMR_modified**2** may be used to calculate new power levels of the NC base stations by subtracting or adding the NMR_modified**2** parameters to the original NMR parameters.

The modified NMR may be compared to one or more of the NUG(s). In the previous examples, the power of the serving BS and the NC with the highest signal power level were used to obtain the relative power modification quantities. The signal power level of the serving BS and/or the NC having the highest signal power may be used solely to modify the NMR, and may not be included in comparison operations against the NUG(s). If the serving BS power level parameter and/or the NC having the highest signal power level parameter are excluded from the comparison to the NUG(s), the first and/or additional terms of the NMR may be ignored during the comparison operation. Of course, any other parameter may be utilized and the example above including power level should not limit the scope of the claims appended herewith.

To further illustrate modification of the NMR, consider a particular implementation where the variable RxLevNeigh_h_WD represents the received signal strength of a neighboring BS's control channel (neighbor A) having the highest signal level, as measured by the wireless device. RxLevNeigh_h_WD may be listed first in a measurement report list containing signal strengths sorted in descending order (h=1). Let RxLevNeigh_i_WD represent the received signal strength of the $i^{th}$ neighbor's control channel measured (neighbor i, where i≠h), as by the wireless device, and RxLevNeigh_h_DB represent the received signal strength of the neighbor (neighbor A) with the highest received signal strength, as measured by the wireless device, and which may be stored in the PDE **50** database during a calibration process. RxLevNeigh_i_DB may be used to represent the received signal strength of the $i^{th}$ neighboring BS's control channel (neighbor i, where i≠h, and i=1 to N, and where N is the number of neighbors reported). RxLevNeigh_i_DB may be stored in the PDE **50** database during a calibration process.

In this example, correlation may be conducted over the received signal strengths of the NC-BSs relative to the NC-BS having the highest received signal strength, as observed by the wireless device. A comparison may include computing the difference between the parameters of the serving BS and the $i^{th}$ neighbor's parameters (i.e. (RxLevNeigh_h_WD−RxLevNeigh_i_WD) and (RxLevNeigh_h_DB−RxLevNeigh_i_DB)). Comparisons may also be conducted for any one, combination of or all of the measured parameters of the NC-BSs.

NM data may be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations by an amount relative to the average signal strength of one or more NC base stations. Each signal power or parameter component of the NMR may also be modified by an average

signal power or parameter level based on one or more of the measured NC signal power levels. The average received signal power level may be calculated a number of different ways, for example, the average of the two highest signal powers, the three highest powers, the average of all (N) signal powers, or an intermediary number between one or more of the measured NC signal power components. Modifying the original NMR components may include subtracting or adding to the existing NMR power components by an amount based on the calculated average, or other various known functions.

To further illustrate modification of the NMR, consider a particular implementation where RxLevNeigh_avg_WD represents the average received signal strength based upon a number of control channel signal powers of neighboring BSs, as measured by the wireless device at an unknown location to be estimated. Let RxLevNeigh_$i_1$.WD represent the received signal strength of the $i^{th}$ neighbor's control channel signal power, and RxLevNeigh_avg_DB represent the average received signal strength of data stored during calibration, and computed based on the neighboring BSs, as measured by the wireless device and used in computing the average received signal strength. The same neighboring BSs may be used to represent the average received signal strength of the signal power levels received by the wireless device and for the average received signal strength of calibration data stored in the PDE **50** database. Let RxLevNeigh_i_DB represent the received signal strength of the $i^{th}$ neighbor's control channel stored in the PDE **50** database during the calibration process (i=1 to N, where N is the number of neighbors reported).

In this example, a comparison may be conducted over the received signal strengths of the neighboring BSs relative to the average received signal strength computed for all neighboring BSs observed by the wireless device (i.e., compare between (RxLevNeigh_avg_WD−RxLevNeigh_i_WD)) and for all neighbors previously measured by the wireless device (i.e., compare between (RxLevNeigh avg_DB−RxLevNeigh_i_DB)). The average signal power level observed over all the neighbor signal power levels may be realized in absolute powers (mW) or in relative powers (dBm).

Any combination of the above NMR modification procedures may be performed to increase the accuracy of mobile station location estimates. Further, any number of or type of parameters may be utilized in any of the aforementioned procedures and the exemplary parameters of power level, signal strength, etc. should not limit the scope of the claims appended wherewith. Certain factors impacting the modification procedure selection process may include the specific type of cellular technology, the geographical terrain and/or environmental conditions, etc. Further, the present subject matter acknowledges that some NMR modification procedures may be best suited for outdoor location estimation, while others are better suited for indoor location estimation, and some even may be best for mixed (indoor & outdoor) location estimation.

For example, if the serving BS for a mobile station is known to be in an area where there are no buildings or obstructions then it may be prudent to leave the NM data unmodified or select the NMR modification procedure where the serving base station is used as the basis to calculate NMR modifications. Further, if the serving cell is in a geographical area with known large obstructions (e.g., buildings, mountains etc.) then it may be prudent to use the NMR modification procedure that selects the NC base station having the highest signal power as the basis to calculate NMR modifications. Additionally, if the serving cell is in an area containing both outdoor and indoor facilities, then it may be best to use the average of more than one NC signal power value as the basis to modify the NMR(s).

Regardless of the type of modification algorithm selected to modify the NM data, a margin of error may still be present when attempting to determine the precise location of a mobile station. Determining the amount of location error may be useful when estimating the likelihood of accurately locating a mobile station. A confidence measure may also be used to represent the accuracy of a mobile station's estimated location.

The value of a confidence measure may vary depending on the estimated accuracy of the location estimated. If estimated locations derived from mapping NM data to a given location, whether using a NUG or other form of a data source for comparison purposes, agree under any or all combinations, the respective confidence measure "C" may be considered high. A confidence measure may also be represented as a function that increases as the quantity of measured data correctly matches data associated with a final estimated location. An exemplary confidence measure or function may be represented as a fraction of all locations that are similar to the final estimated location, however, such an example should not limit the scope of the claims appended herewith.

After one or more of the data modification procedures have been calculated, respective confidence measures may be calculated to represent the likely accuracy of the modification procedures. Confidence measures may then be compared and the best one selected to represent the appropriate modification procedure to implement.

Certain estimated locations may be assigned weights by using a confidence measure as a weight to represent the probability of locating a mobile station at a given location. For example, confidence measures may be based on one or more calculated parameters, including, but not limited to: a probability density function (PDF), a joint PDF, Mahalanobis distance, distortion measure, ordered number parameter, timing advance (TA) parameter, mobile orientation etc. The calculated parameters may be derived from the NUG calibration data stored in the PDE **50** database. The parameters may be pre-stored in memory or may be calculated during a NMR to NUG comparison operation.

Probability density functions may be calculated based on an individual NC base station power level, or a set of multiple NC base station power levels. The calculated probability density function may be compared to the set of available NUGs (i.e., NUGS **1-3** of FIG. **1**) to determine a probability that the NM data matches a particular NUG location. A joint probability may also be calculated over a set of probabilities to further estimate the location of the mobile station. The results of the calculated PDF may be used in a number of estimation techniques to locate the mobile station.

Distortion measures may be determined at a particular location may be included in a NMR and used in a comparison operation to measure the difference in distortion between NUG data and NM data. The distortion measures may be used to estimate a location of a mobile station based on the results of the comparison.

A Mahalanobis distance may be an exemplary distortion measure and may utilized to assist in identifying and analyzing different patterns in a wireless communications environment. The Mahalanobis distance may also be useful in determining similarities between an unknown sample data set and a known data set.

Ordering number lists may also be used to organize parameters for comparison purposes. An ordering number list may be a list or table of data parameters organized in a particular

order. The power levels may be listed in descending order and compared to similar parameters associated with a NUG(s). A threshold power level may be used to represent an acceptable amount of deviation between a comparison of power levels obtained from a NMR(s) and/or a NUG(s). If one or more power levels in the NMR(s) and the NUG(s) fall within an acceptable range of one another, the location of a mobile station may be measured with a corresponding degree of accuracy.

Each generated NMR may be used to provide an individual estimate of the mobile station's location. The PDE **50** may receive a number of NMRs over a period of time, a corresponding number of location estimates may be generated based on the number of NMRs received. These estimates may be combined in a statistical algorithm and may provide a more accurate location estimate than the individual NMRs.

Given a particular NMR or set of NMR(s) containing data collected outdoors, a selection procedure may be conducted to select the most appropriate modification procedure to use when modifying the NM data. Once one or more of the above described NMR modification procedures have been calculated, (e.g., non-modification, serving cell power level, highest NC power level, average(s) of the NC power levels, etc.) one or more of these calculations may be selected as an optimal solution to be used to modify the NMR.

One way to determine the optimal solution that should be used to modify the NMR is to calculate a confidence measure for each of the calculated modification procedures. Once the confidence measures have been calculated, the optimal solution may be selected as the modification procedure with the highest confidence measure. Alternatively, a location estimate may be made by weighting the individual solutions by the applicable confidence measure and combining the results into a single NMR solution.

Combining multiple NMR(s) may generate a location estimate with increased accuracy. When comparing NM data to a NUG, the grid point data that most closely matches the NM data may become the estimated location of the mobile station. In an alternative arrangement, interpolation may be used for determining a location that falls between two grid points to provide an even more accurate location estimate. Applying probabilistic weights, hypotheses and deriving confidence measures may increase the accuracy of the location estimates. Utilizing exemplary probabilistic measures, the estimated location of a mobile station may be determined within a particular degree of certainty. A similar approach may also be applied to select the appropriate NMR modification procedure to accommodate for varying conditions and other operational variables (e.g., different air standards, varying environmental circumstances, etc.).

FIG. **2** illustrates a flow diagram **200** of a method to locate a mobile station. Observed network measurement data may be collected (operation **201**). The observed data would typically be the same or similar to the data in a network measurement report (NMR). The network measurement data represents at least one network characteristic observed by the mobile station operating at a particular location within a region. The NM data may be compared to calibration database data, where the calibration database data represents calibration data measured within the geographical area of the region (operation **202**). The location of the mobile station may be estimated based on the comparison of the modified network measurement data and the calibration database data (operation **203**).

FIG. **3** illustrates a flow diagram **300** of a method to locate a mobile station in an indoor environment. Calibration data samples are collected in an outdoor environment (operation **301**). At least one attenuation variable may be applied to the calibration data sample to simulate an indoor environment (operation **302**). The modified network measurement data sample may be applied to a mobile station location algorithm (operation **303**). The mobile station may be then located in the indoor environment based on the mobile station location algorithm implementing the at least one modified calibration sample (operation **304**).

FIG. **4** illustrates a flow diagram **400** of a method to locate a mobile station. NM data may be obtained to represent at least one network characteristic of the mobile station's serving base station and at least one second network characteristic of at least one of the mobile station's neighboring base stations (operation **401**). The difference between the at least one first signal characteristic and the at least one second signal characteristic may be computed (operation **402**). At least one signal characteristic of the NM data may be adjusted based on the computed difference (operation **403**). The mobile station may be then located based on the modified network measurement data (operation **404**).

FIG. **5** illustrates a flow diagram **500** of a method to locate a mobile station. NM data may be obtained (operation **501**), which represents at least one first network characteristic of the mobile station's serving base station, and at least one second and third network characteristic of the mobile station's at least two neighboring base stations. It may be then determined which base station has the highest signal power at a particular location (operation **502**). The difference between the highest signal power at the particular location and the power levels at the particular location of the serving base station and the remaining neighboring base stations may be determined (operation **503**). At least one signal characteristic of the NM data may be adjusted based on the computed differences (operation **504**). The mobile station may then be located based on the modified NMR (operation **505**).

FIG. **6** illustrates a flow diagram **600** of a method to locate a mobile station. A NMR may be obtained (operation **601**), which represents at least one first signal characteristic of the mobile station's serving base station, and at least one second and third signal characteristics of the mobile station's at least two respective neighboring base stations. A difference may be computed between the at least one first signal characteristic of the mobile station's serving base station and the at least one second signal characteristic of at least one of the mobile station's neighboring base stations to determine a first solution (operation **602**). It may then be determined which base station has the highest signal power level at a particular location (operation **603**). The difference between the highest signal power and the power levels of the serving base station and the remaining neighboring base stations may be determined as a second solution (operation **604**). The neighboring base station having the lowest signal power level at the particular location may be determined (operation **605**). An average signal power level intermediary to the difference between the highest signal power level and the lowest signal power level may be determined as a third solution (operation **606**). It may then be determined which solution is a most optimal solution by comparing the three solutions (operation **607**). The signal characteristic of the NM data may then be adjusted based on the most optimal solution (operation **608**). The mobile station may then be located based on the adjusted NM data (operation **609**).

FIG. **7** illustrates an embodiment of the present subject matter. The method includes providing a database of previously-gathered calibration data for a predetermined region in a wireless network (operation **701**). The database may be a collection of data from uniform or non-uniform grids that

contain network measurements with associated location estimates. Network measurement data may be then observed and measured typically by a mobile station or any other wireless device (operation **703**). The network measurement data may include received base station power and timing advance, as well as other network characteristics observable by a mobile station. The observed network measurement data may then be modified (operation **705**). This modification may include applying an attenuation function to some or all of the network measurement data or converting absolute values into relative values. The modification may be performed by a processor, microprocessor or ASICS. The modified network measurement data may then be compared to the calibration database in order to determine the location of the mobile station (operation **707**). The comparison may be performed by a processor, microprocessor or ASICS.

FIG. **8** is another illustration of an embodiment of the present subject matter. A database of previously-gathered calibration data for a predetermined region in a wireless network may be provided (operation **801**). Observed network measurement data may be collected which includes a first signal characteristic from the mobile's serving transmitter (operation **803**). The observed network measurement data may be modified as a function of the first signal characteristic (operation **805**), for example the first signal characteristic may be received power and the modification may be a function of the relative value with respect to the received power. The modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **807**).

FIG. **9** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of calibration data for a region may be provided (**901**). Network measurement data from transmitters may be observed and collected including a signal characteristic from each of the transmitters (operation **903**). An average value for the signal characteristic among the transmitters may be determined (operation **905**). The average for the signal characteristic may be a weighted average. The observed network measurement data may be modified using the determined average value (operation **907**) and the modified network measurement data may be compared with the database of calibration data to determine the location of the mobile station (operation **909**).

FIG. **10** is an illustration of an embodiment of the present subject matter for determining a location of a mobile station. A database of previously-gathered outdoor calibration data for a predetermined region in a wireless network may be provided (operation **1001**). Network measurement data may be observed and collected (operation **1003**). The network measurement data may be compared with the database of calibration data to thereby determine a plurality of location estimates for the mobile station (operation **1005**). The location estimates may be derived using modified, unmodified, limited signal characteristics, several signal characteristics, etc. For each location estimate, a confidence measure may be determined (operation **1007**). A location may be determined based on the plurality of location estimates and their respective confidence measures (**1009**). For example, the location may be determined based on a weighted average, where the weights are directly proportional to the confidence measures.

The embodiments described above may be used in communication devices, such as, a base station, having varying configurations that include, but are not limited to: predetermined calibration data collected over varying terrain, different base station configurations, varying cellular communication protocols, etc.

While preferred embodiments of the present invention have been described, it is to be understood that the embodiments described are illustrative only and the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalents, many variations and modifications naturally occurring to those skilled in the art from a perusal hereof.

What is claimed is:

**1**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network;

collecting observed network measurement data, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;

modifying said observed network measurement data; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**2**. The method of claim **1** wherein said database comprises previously-gathered calibration data at one or more predetermined calibration points within said region.

**3**. The method of claim **2** wherein said previously-gathered calibration data at one or more predetermined calibration points is combined to form previously-gathered calibration data for one or more non-uniform grid points within said region.

**4**. The method of claim **1** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**5**. The method of claim **1** wherein said previously-gathered calibration data includes signal strength information measured at a predetermined calibration point within said region for a signal transmitted from a known location within or in proximity to said region.

**6**. The method of claim **1** wherein said previously-gathered calibration data includes signal strength information measured by a receiver at a known location within or in proximity to said region for a signal transmitted from a predetermined calibration point within said region.

**7**. The method of claim **1** wherein said previously-gathered calibration data includes round trip time information for signals traveling between a predetermined calibration point within said region and a known location within or in proximity to said region.

**8**. The method of claim **1** wherein said previously-gathered calibration data includes time difference of arrival information for a first signal traveling between a first known location and a predetermined calibration point within said region and a second signal traveling between a second known location and said calibration point.

**9**. The method of claim **1** wherein said previously-gathered calibration data includes information identifying a serving cell of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**10**. The method of claim **1** wherein said previously-gathered calibration data includes information identifying a serving sector of a transmitter transmitting a signal received at a predetermined calibration point within said region.

**11**. The method of claim **1** wherein said previously-gathered calibration data includes information regarding a state of said wireless network.

**12**. The method of claim **1** wherein said previously-gathered calibration data includes calibration data gathered at a

predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**13**. The method of claim **12** wherein said observed network measurement data is collected at a mobile station located within a structure.

**14**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network, wherein said network includes a serving transmitter;

collecting observed network measurement data including a first signal characteristic from said serving transmitter, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;

modifying said observed network measurement data using said first signal characteristic; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**15**. The method of claim **14** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**16**. The method of claim **14** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**17**. The method of claim **16** wherein said observed network measurement data is collected at a mobile station located within a structure.

**18**. The method of claim **14** wherein said first signal characteristic is signal strength.

**19**. The method of claim **18** wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.

**20**. The method of claim **19** wherein the modifying of said calibration data uses a difference between said first and second signal characteristics.

**21**. The method of claim **14** wherein said first signal characteristic is signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.

**22**. The method of claim **21** wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.

**23**. The method of claim **14** wherein said observed network measurement data includes a data set comprising:

$$[P_1, \ldots P_n, TA]$$

where:

$P_1$ represents the signal strength of said serving transmitter as measured at said mobile station,

$P_n$ represents a signal strength of at a $n^{th}$ neighboring transmitter as measured at said mobile station, and

TA represents a timing advance parameter;

and wherein said modified network measurement data includes a data set comprising:

$$[0, \ldots P_1\text{-}P_{n-1}, P_1\text{-}P_n, TA]$$

where:

0 represents a difference between $P_1$ and $P_1$,

$P_1\text{-}P_{n-1}$ represents a difference between $P_1$ and $P_{n-1}$, and

$P_1\text{-}P_n$ represents a difference between $P_1$ and $P_n$.

**24**. The method of claim **23** wherein said first neighboring transmitter is not a member of said wireless network.

**25**. A method for determining a location of a mobile station, comprising:

providing a database of previously-gathered calibration data for a predetermined region in a wireless network;

collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters, the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;

determining an average value for select ones of said signal characteristics;

modifying said observed network measurement data using said average value; and

comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.

**26**. The method of claim **25** wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

**27**. The method of claim **25** wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.

**28**. The method of claim **25** wherein said observed network measurement data is collected at a mobile station located within a structure.

**29**. The method of claim **25** wherein said signal characteristic is signal strength.

**30**. The method of claim **29** wherein the modifying of said calibration data uses a difference between said average value and said signal characteristic for a first one of said plural transmitters.

**31**. The method of claim **25** wherein said signal characteristic is signal strength of a control channel.

**32**. The method of claim **25**, wherein the observed network measurement data includes received signal strength of said transmitters as said mobile station.

**33**. The method of claim **25** wherein said observed network measurement data includes a data set comprising:

$$[P_1, P_2, P_3, TA]$$

where:

$P_1$ represents the signal strength of a first one of said plural transmitters as measured at said mobile station,

$P_2$ represents a signal strength of a second one of said plural transmitters as measured at said mobile station wherein $P_2 > P_1$,

$P_3$ represents a signal strength of a third one of said plural transmitters as measured at said mobile station wherein $P_2 > P_3$, and

TA represents a timing advance parameter;

and wherein said modified network measurement data includes a data set comprising:

$$[P_1\text{-}P_{AVG}, P_2\text{-}P_{AVG}, P_3\text{-}P_{AVG}, TA]$$

where:

$P_{AVG}$ represents an average value of $P_1$, $P_2$, and $P_3$,

$P_1\text{-}P_{AVG}$ represents a difference between $P_1$ and $P_{AVG}$,

$P_2\text{-}P_{AVG}$ represents a difference between $P_2$ and $P_{AVG}$,

$P_3\text{-}P_{AVG}$ represents a difference between $P_3$ and $P_{AVG}$.

**34**. The method of claim **33** wherein said first transmitter is a serving transmitter for said mobile station and said second and third transmitters are neighboring transmitters.

**35**. The method of claim **25** wherein at least one of said plurality of transmitters is not a member of said wireless network.

* * * * *

US008406753B2

(12) **United States Patent**
**Alles et al.**

(10) **Patent No.: US 8,406,753 B2**
(45) **Date of Patent: Mar. 26, 2013**

(54) **SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS**

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(73) Assignee: **Andrew LLC**, Hickory, NC (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1135 days.

(21) Appl. No.: **12/026,480**

(22) Filed: **Feb. 5, 2008**

(65) **Prior Publication Data**

US 2008/0188237 A1 Aug. 7, 2008

**Related U.S. Application Data**

(60) Provisional application No. 60/899,379, filed on Feb. 5, 2007.

(51) **Int. Cl.**
***H04W 4/00*** (2009.01)
*H04W 24/00* (2009.01)

(52) **U.S. Cl.** ..... **455/422.1**; 455/425

(58) **Field of Classification Search** ..... 455/422.1, 455/423, 425, 433, 404.2, 456.1–456.3, 435.1–435.5; 340/870.04–870.05, 988–989, 991, 995.18, 340/995.25, 423.19; 342/357.2–357.25, 342/357.62; 702/85, 94–95, 150
See application file for complete search history.

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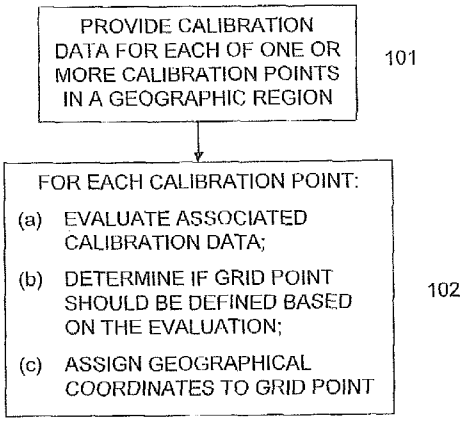
*Primary Examiner* — Melody Mehrpour
*Assistant Examiner* — Emem Stephen
(74) *Attorney, Agent, or Firm* — Duane Morris LLP

(57) **ABSTRACT**

The location of a wireless mobile device may be estimated using, at least in part, one or more pre-existing Network Measurement Reports ("NMRs") which include calibration data for a number of locations within a geographic region. The calibration data for these locations is gathered and analyzed so that particular grid points within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. Sets of grid points may be evaluated as a function of parameters of the calibration data, and a set of grid points may be selected as a function of a predetermined criteria. The location of a mobile device in the geographic region may then be determined as a function of the predetermined criteria.

**57 Claims, 72 Drawing Sheets**



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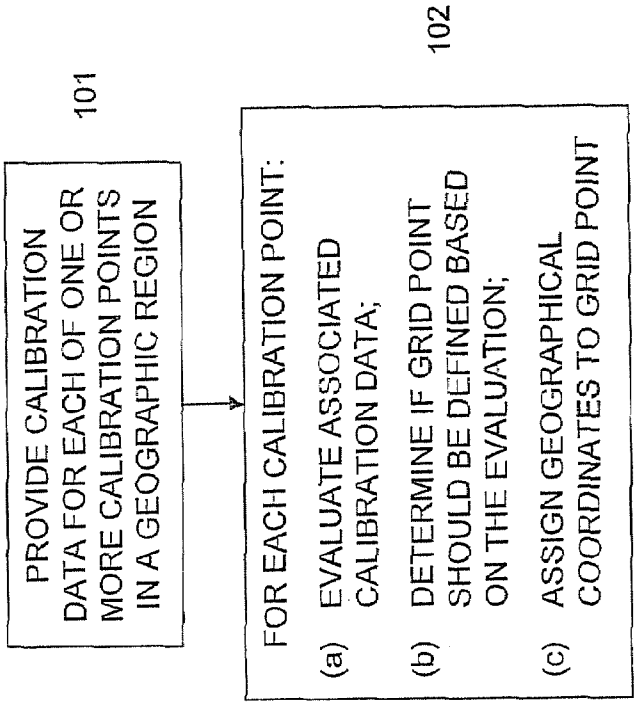

101
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
102
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT

FIGURE 1

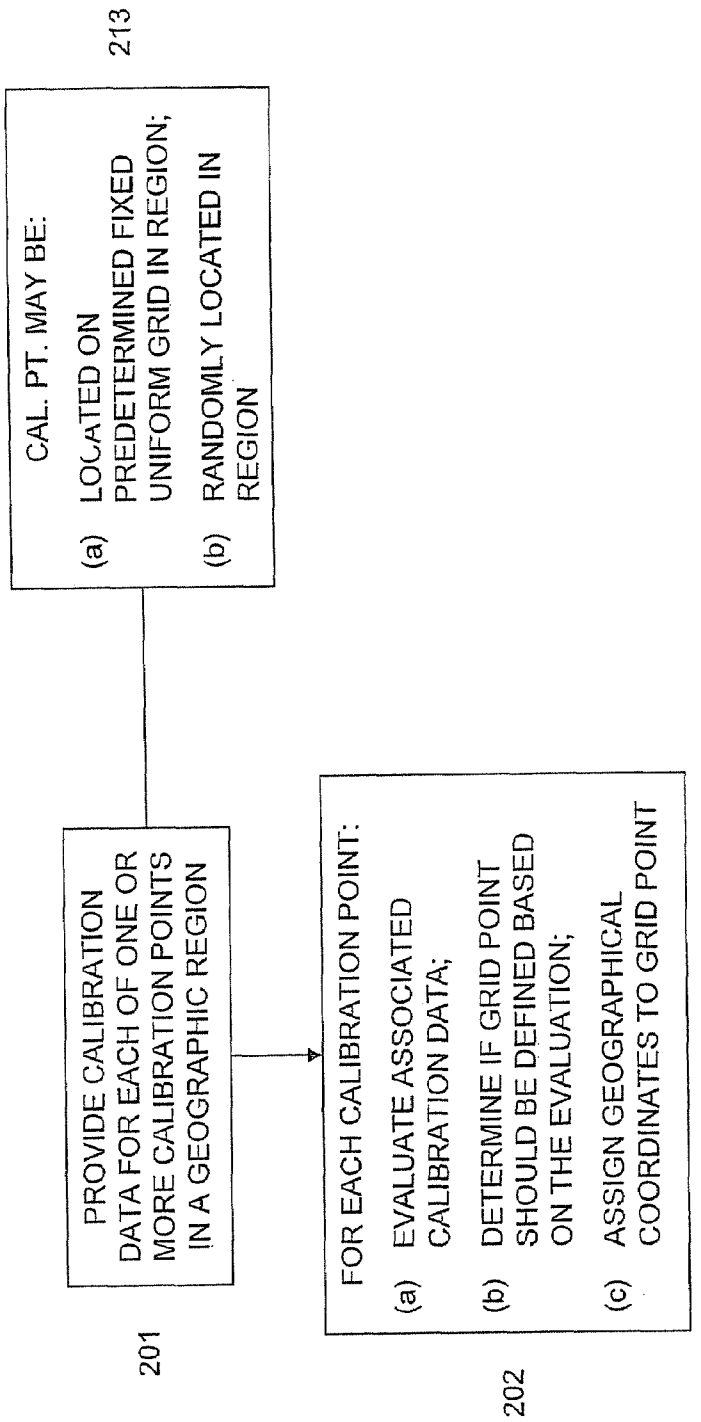

PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
201
CAL. PT. MAY BE:
(a) LOCATED ON PREDETERMINED FIXED UNIFORM GRID IN REGION;
(b) RANDOMLY LOCATED IN REGION
213
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
202

FIGURE 2

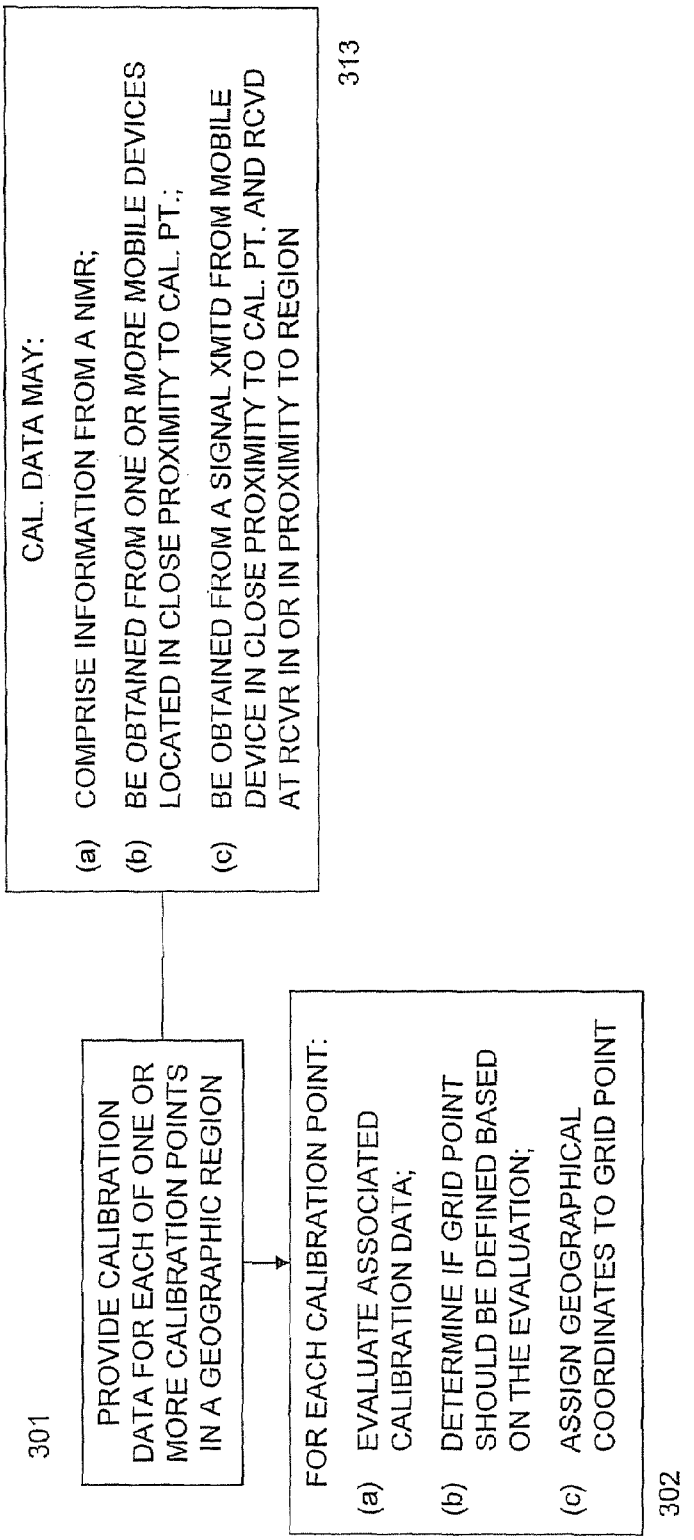

301
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
302
CAL. DATA MAY:
(a) COMPRISE INFORMATION FROM A NMR;
(b) BE OBTAINED FROM ONE OR MORE MOBILE DEVICES LOCATED IN CLOSE PROXIMITY TO CAL. PT.;
(c) BE OBTAINED FROM A SIGNAL XMTD FROM MOBILE DEVICE IN CLOSE PROXIMITY TO CAL. PT. AND RCVD AT RCVR IN OR IN PROXIMITY TO REGION
313

FIGURE 3

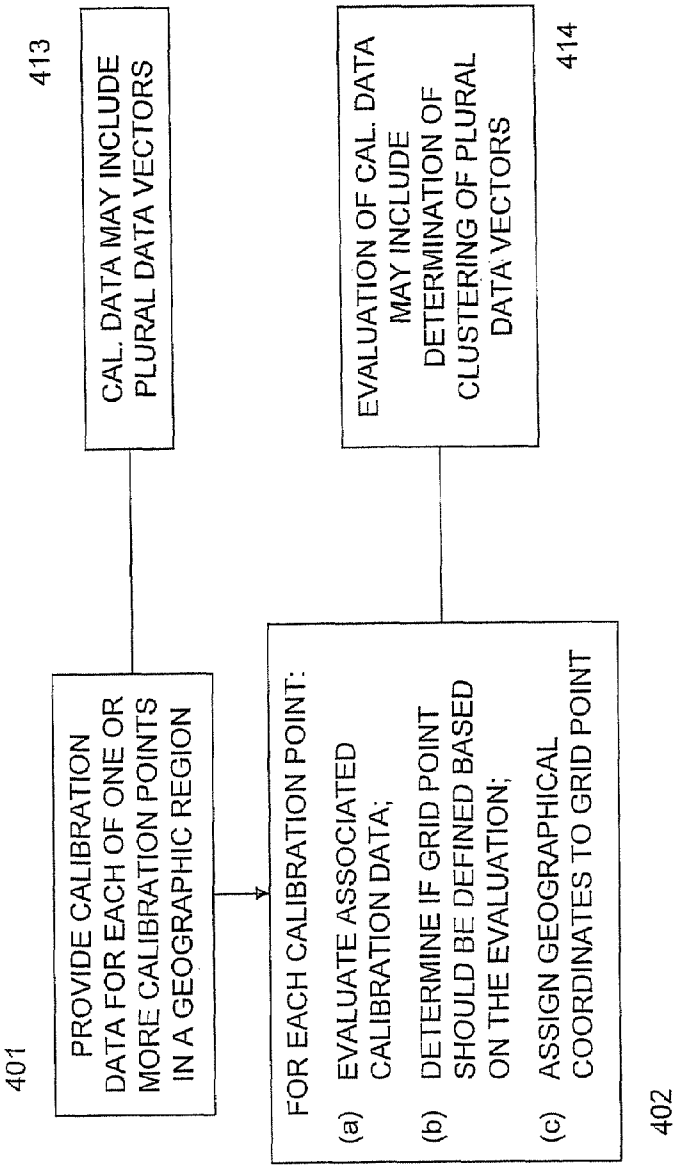

401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
413
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
402
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
414
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS

FIGURE 4

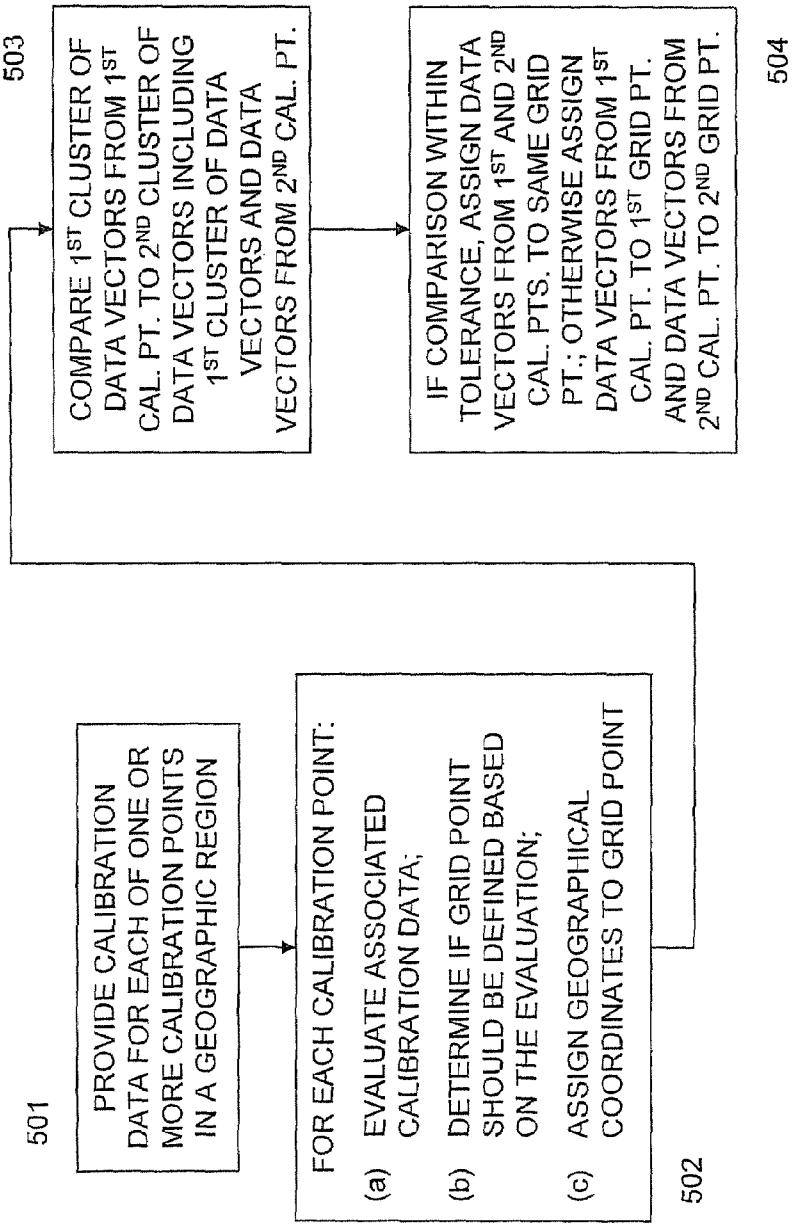

501
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
502
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
503
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS INCLUDING 1ST CLUSTER OF DATA VECTORS AND DATA VECTORS FROM 2ND CAL. PT.
504
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CAL. PTS. TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CAL. PT. TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CAL. PT. TO 2ND GRID PT.

FIGURE 5

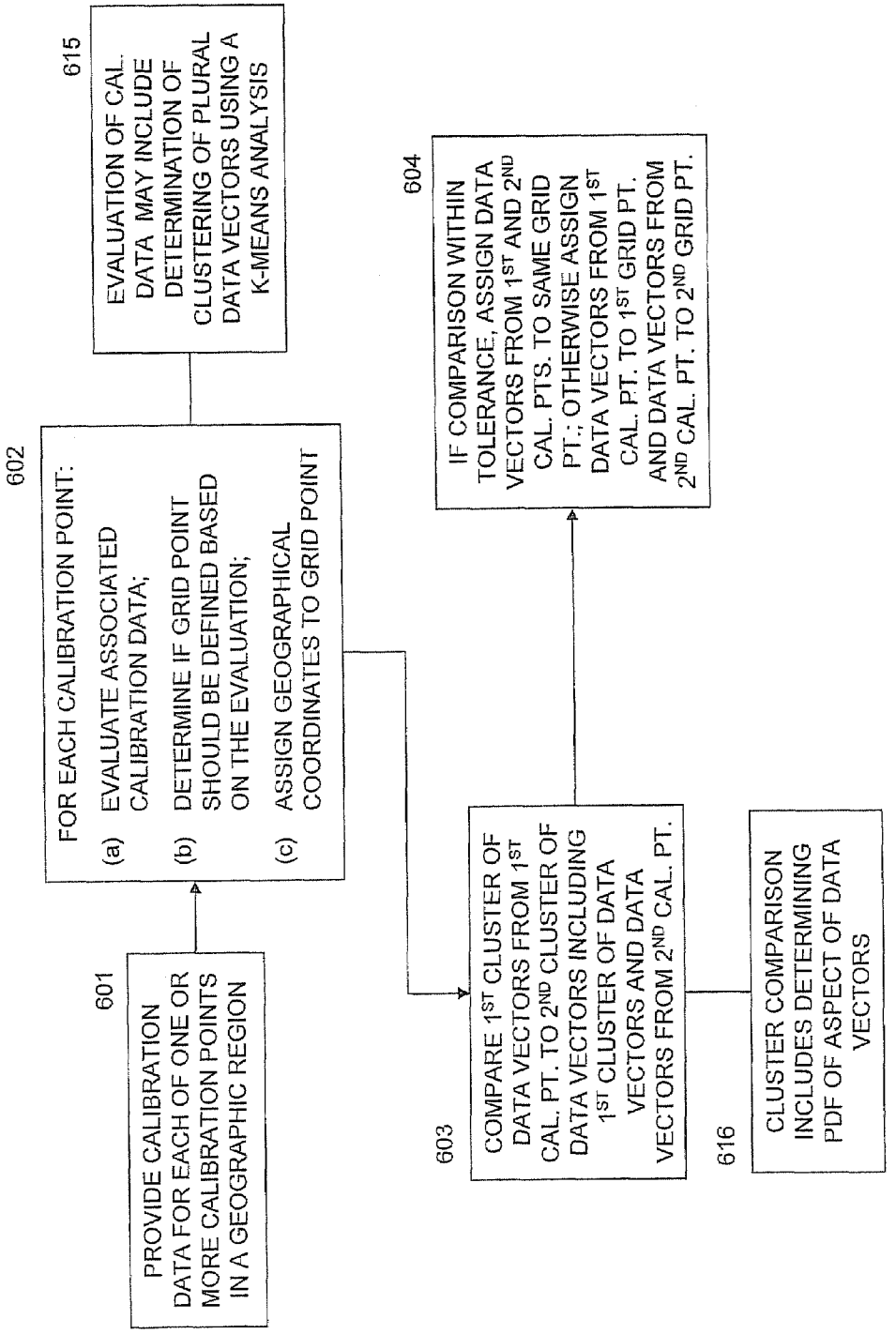

601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
615
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS USING A K-MEANS ANALYSIS
603
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS INCLUDING 1ST CLUSTER OF DATA VECTORS AND DATA VECTORS FROM 2ND CAL. PT.
604
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CAL. PTS. TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CAL. PT. TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CAL. PT. TO 2ND GRID PT.
616
CLUSTER COMPARISON INCLUDES DETERMINING PDF OF ASPECT OF DATA VECTORS

FIGURE 6

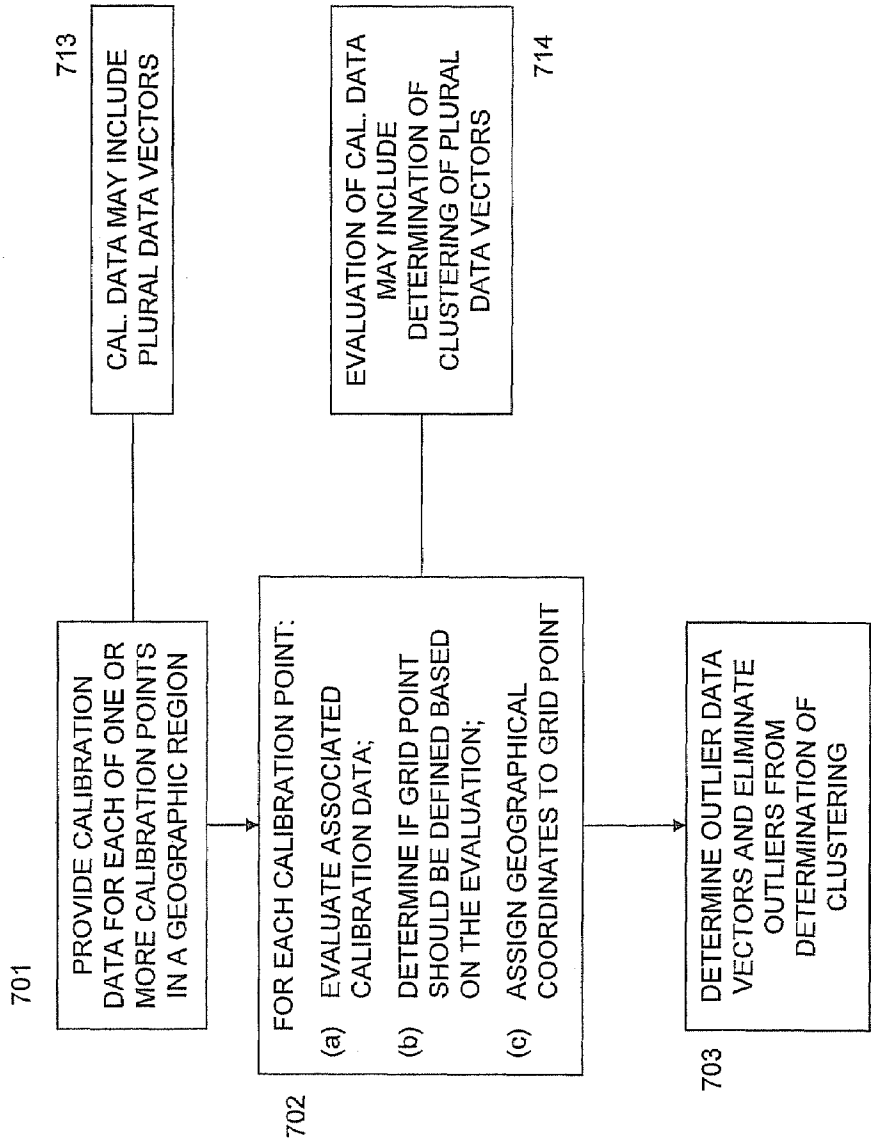

701
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
713
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
702
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
714
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
703
DETERMINE OUTLIER DATA VECTORS AND ELIMINATE OUTLIERS FROM DETERMINATION OF CLUSTERING

FIGURE 7

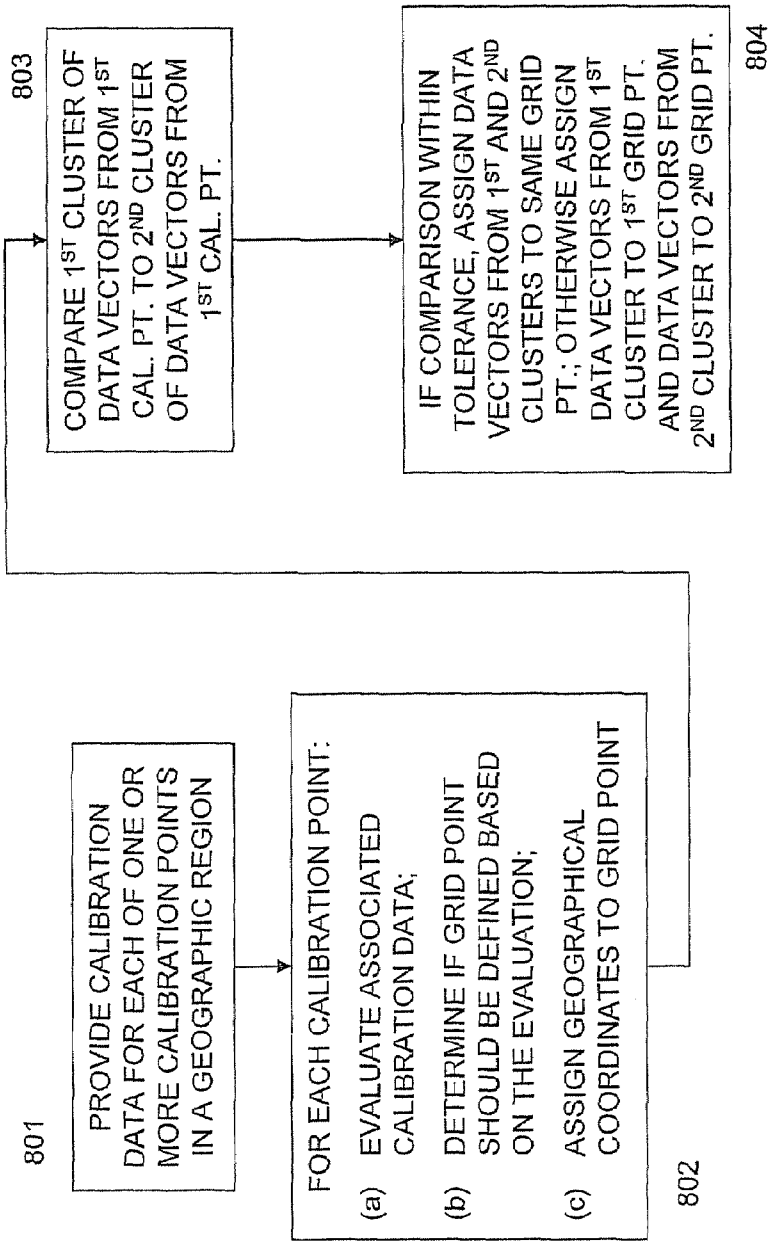

801
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
802
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
803
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
804
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CLUSTERS TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CLUSTER TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CLUSTER TO 2ND GRID PT.

FIGURE 8

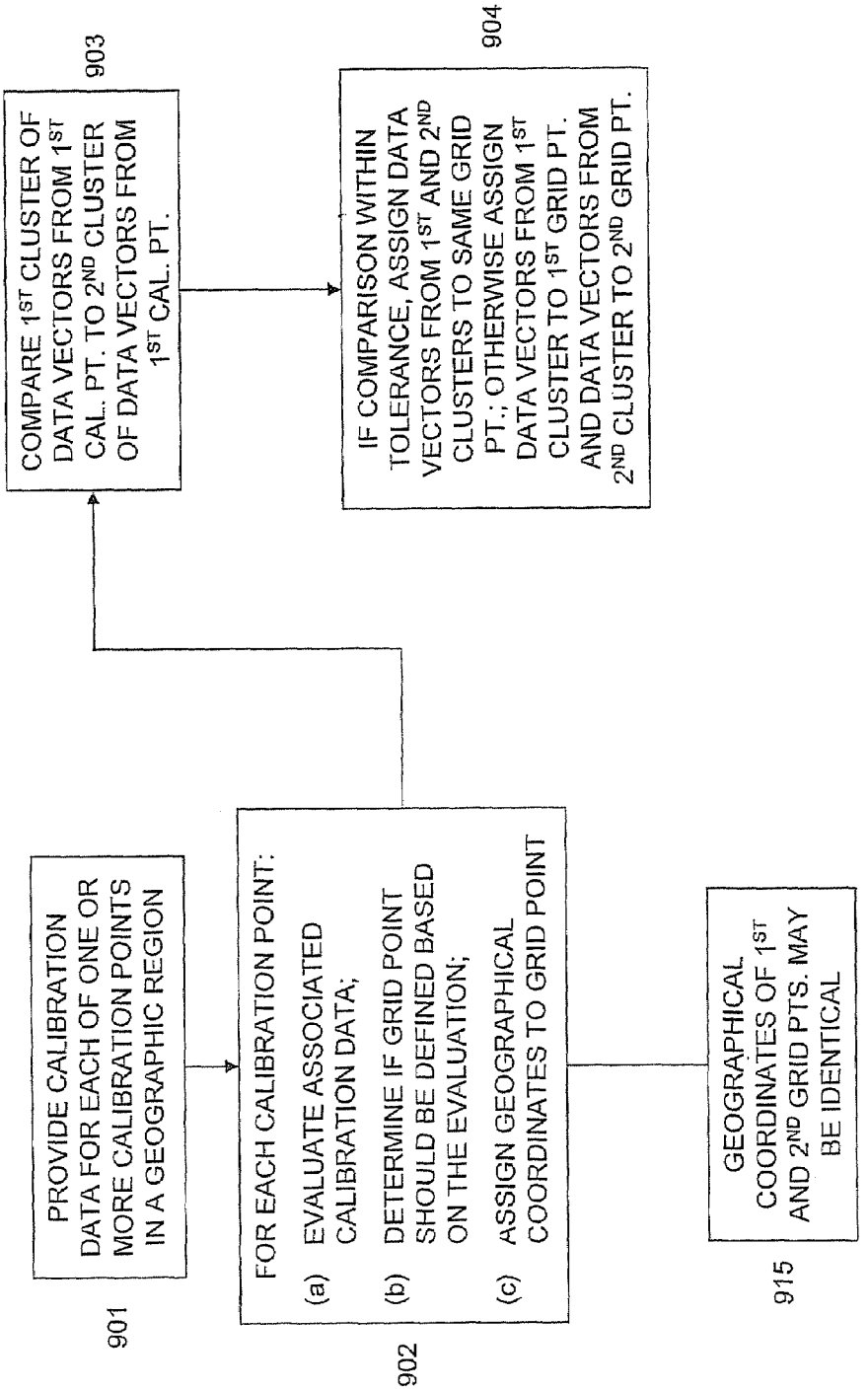

PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
901
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
902
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
903
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CLUSTERS TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CLUSTER TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CLUSTER TO 2ND GRID PT.
904
GEOGRAPHICAL COORDINATES OF 1ST AND 2ND GRID PTS. MAY BE IDENTICAL
915

FIGURE 9

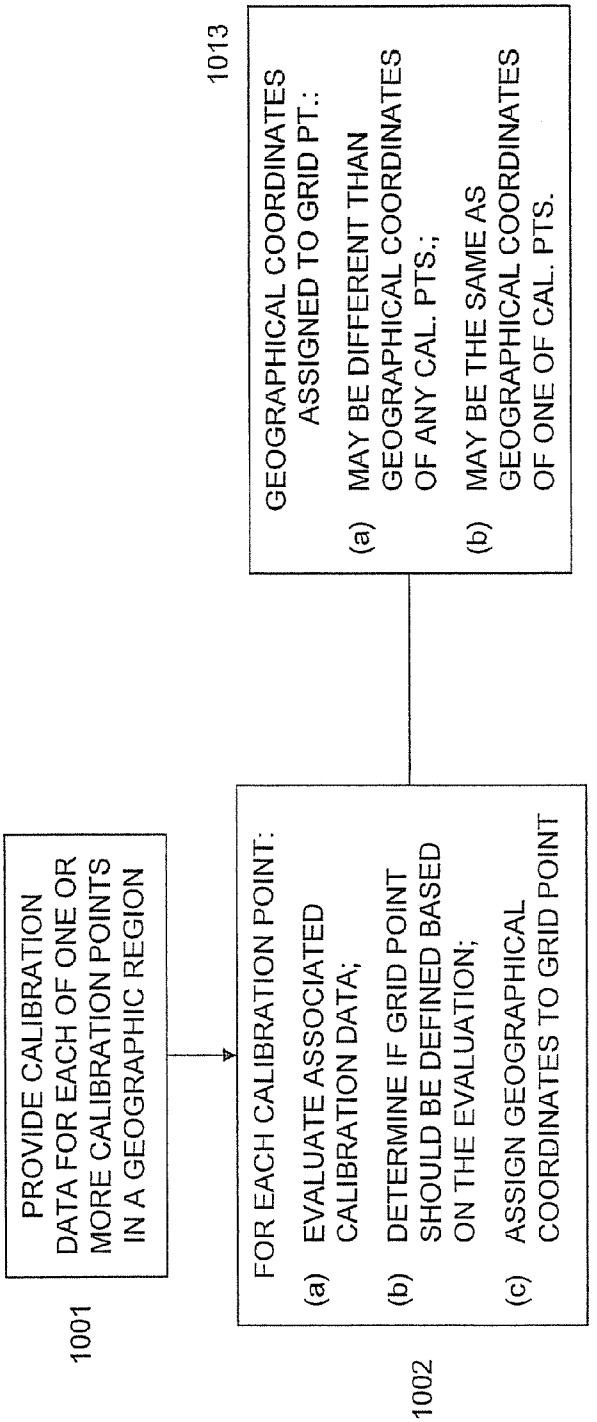

1001
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1002
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1013
GEOGRAPHICAL COORDINATES ASSIGNED TO GRID PT.:
(a) MAY BE DIFFERENT THAN GEOGRAPHICAL COORDINATES OF ANY CAL. PTS.;
(b) MAY BE THE SAME AS GEOGRAPHICAL COORDINATES OF ONE OF CAL. PTS.

FIGURE 10

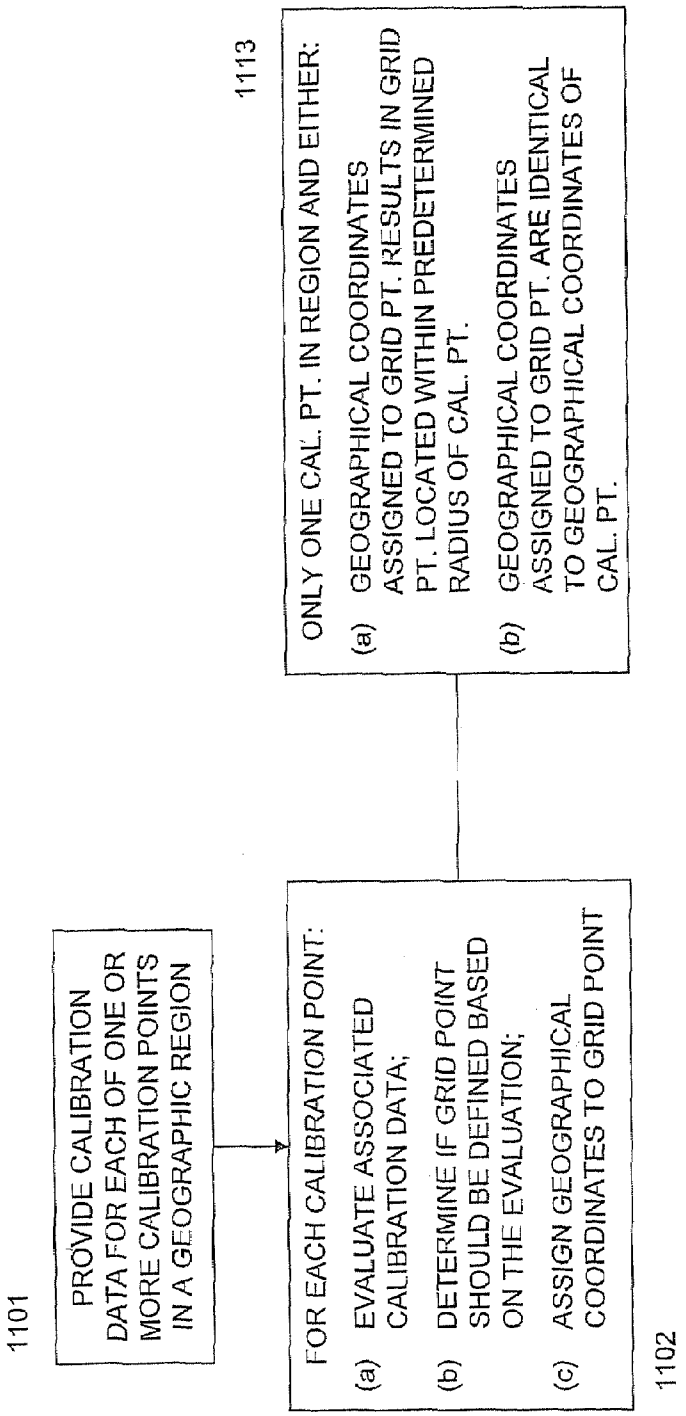

1101
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1102
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1113
ONLY ONE CAL. PT. IN REGION AND EITHER:
(a) GEOGRAPHICAL COORDINATES ASSIGNED TO GRID PT. RESULTS IN GRID PT. LOCATED WITHIN PREDETERMINED RADIUS OF CAL. PT.
(b) GEOGRAPHICAL COORDINATES ASSIGNED TO GRID PT. ARE IDENTICAL TO GEOGRAPHICAL COORDINATES OF CAL. PT.

FIGURE 11

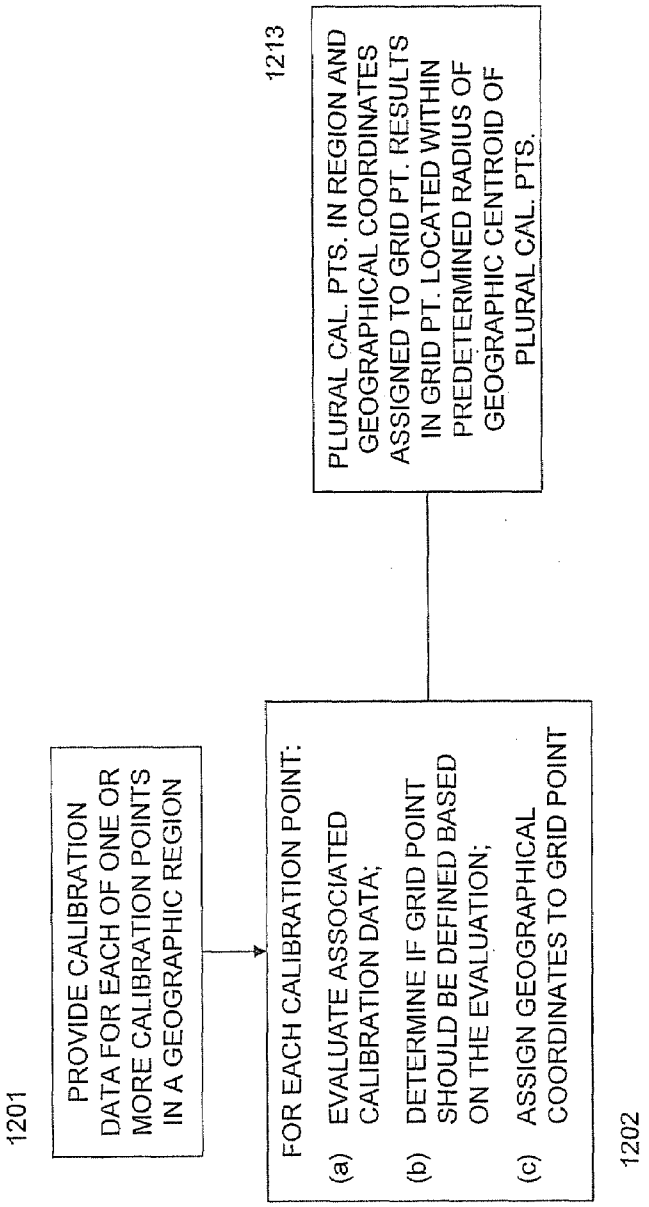

1201
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1202
1213
PLURAL CAL. PTS. IN REGION AND GEOGRAPHICAL COORDINATES ASSIGNED TO GRID PT. RESULTS IN GRID PT. LOCATED WITHIN PREDETERMINED RADIUS OF GEOGRAPHIC CENTROID OF PLURAL CAL. PTS.

FIGURE 12

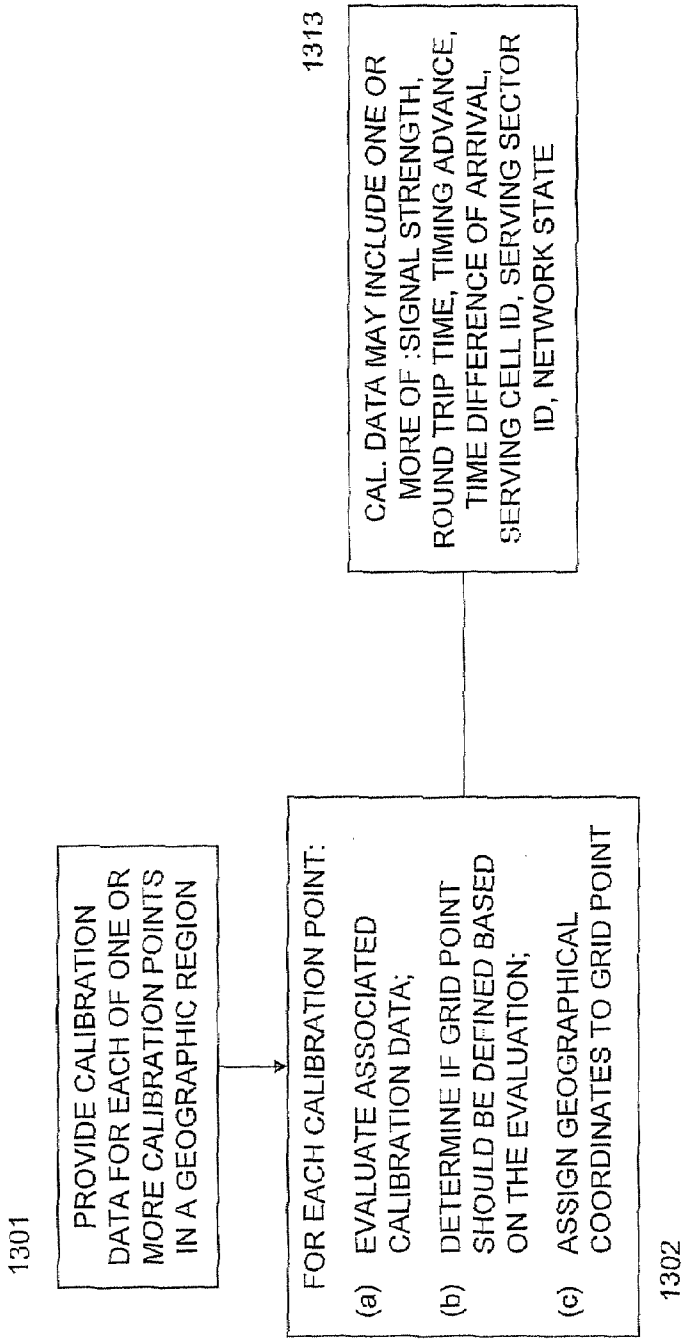

1301
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1302
1313
CAL. DATA MAY INCLUDE ONE OR MORE OF :SIGNAL STRENGTH, ROUND TRIP TIME, TIMING ADVANCE, TIME DIFFERENCE OF ARRIVAL, SERVING CELL ID, SERVING SECTOR ID, NETWORK STATE

FIGURE 13

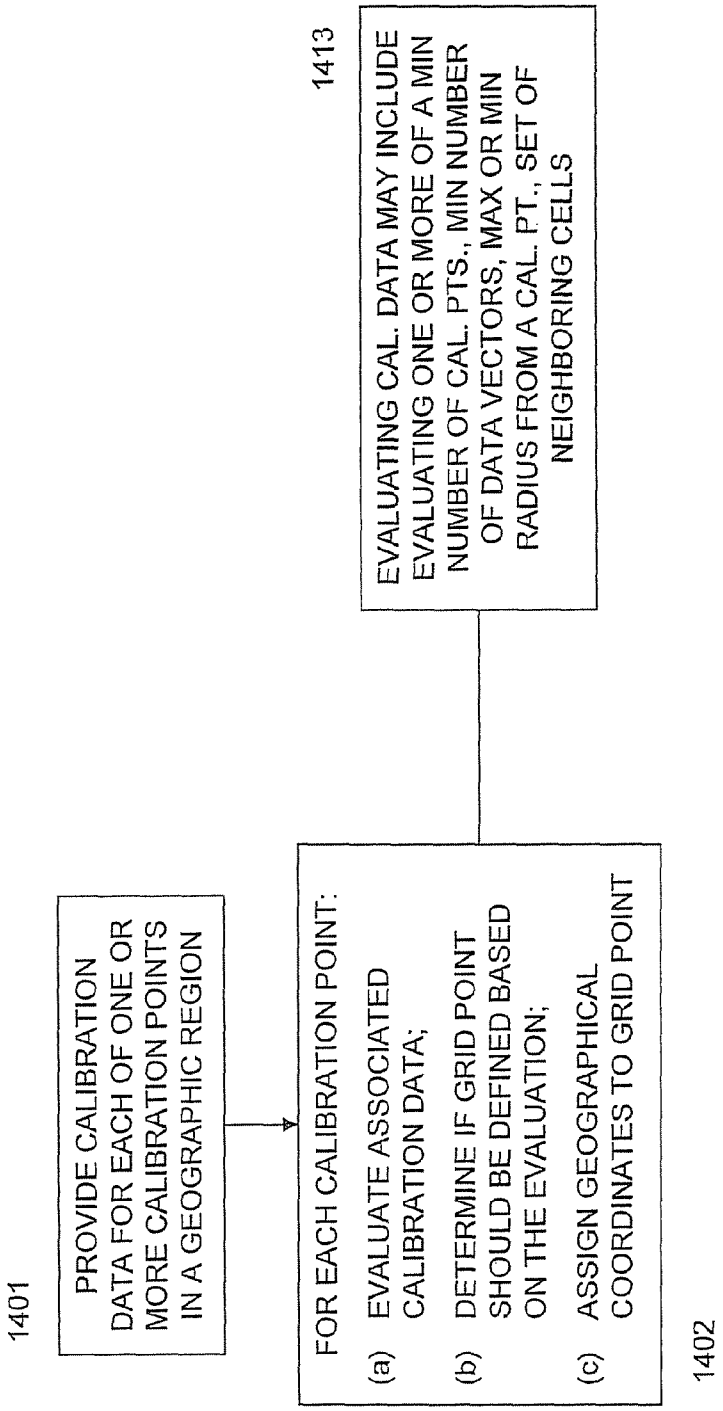

1401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1402
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1413
EVALUATING CAL. DATA MAY INCLUDE EVALUATING ONE OR MORE OF A MIN NUMBER OF CAL. PTS., MIN NUMBER OF DATA VECTORS, MAX OR MIN RADIUS FROM A CAL. PT., SET OF NEIGHBORING CELLS

FIGURE 14

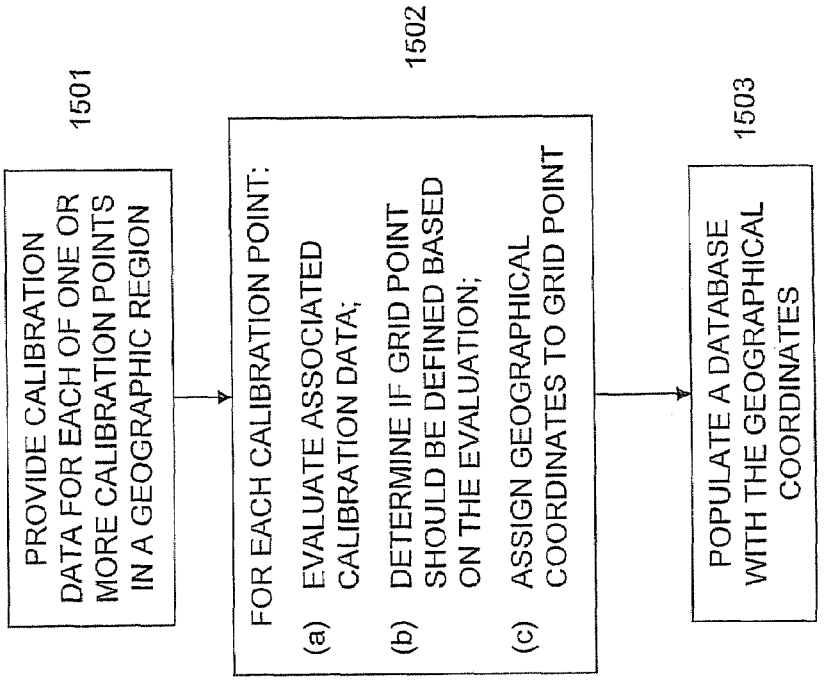

1501
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1502
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1503
POPULATE A DATABASE WITH THE GEOGRAPHICAL COORDINATES

FIGURE 15

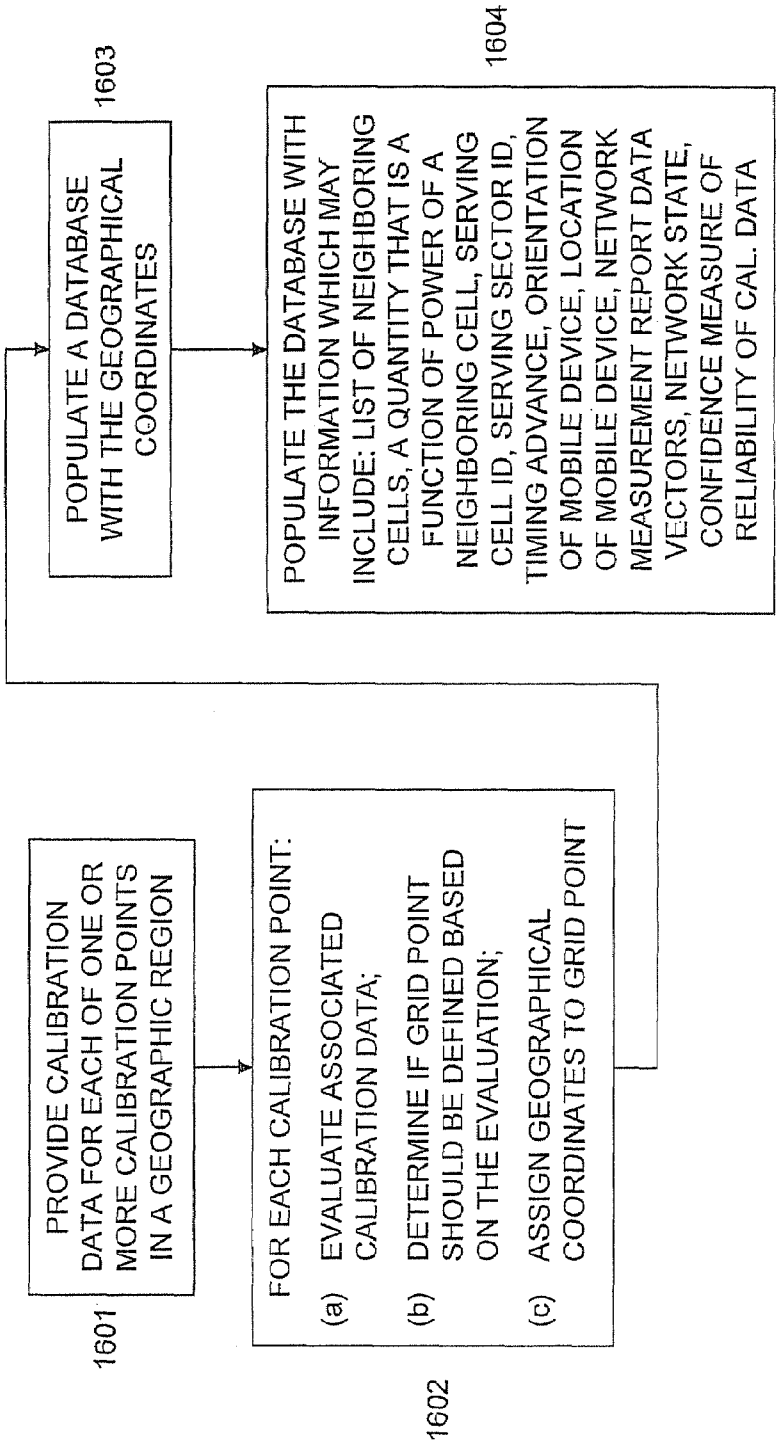

1601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1603
POPULATE A DATABASE WITH THE GEOGRAPHICAL COORDINATES
1604
POPULATE THE DATABASE WITH INFORMATION WHICH MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA

FIGURE 16

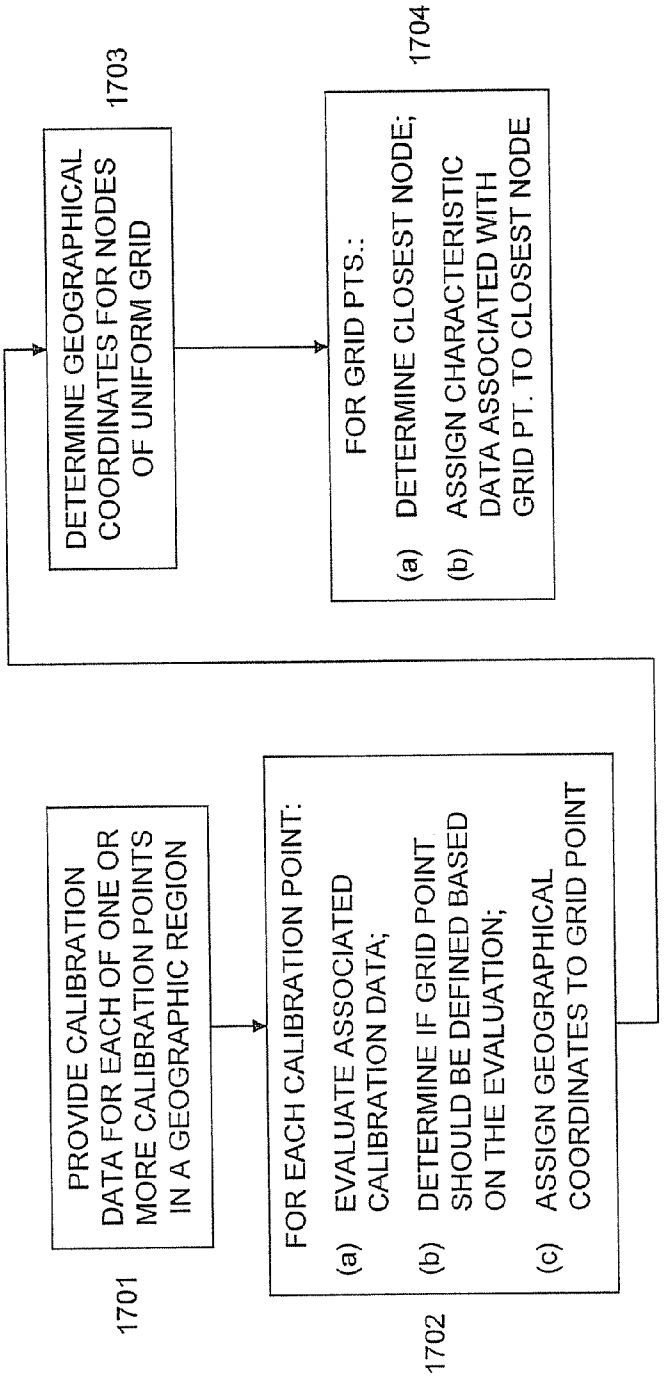

1701
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1702
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1703
DETERMINE GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
1704
FOR GRID PTS.:
(a) DETERMINE CLOSEST NODE;
(b) ASSIGN CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE

FIGURE 17

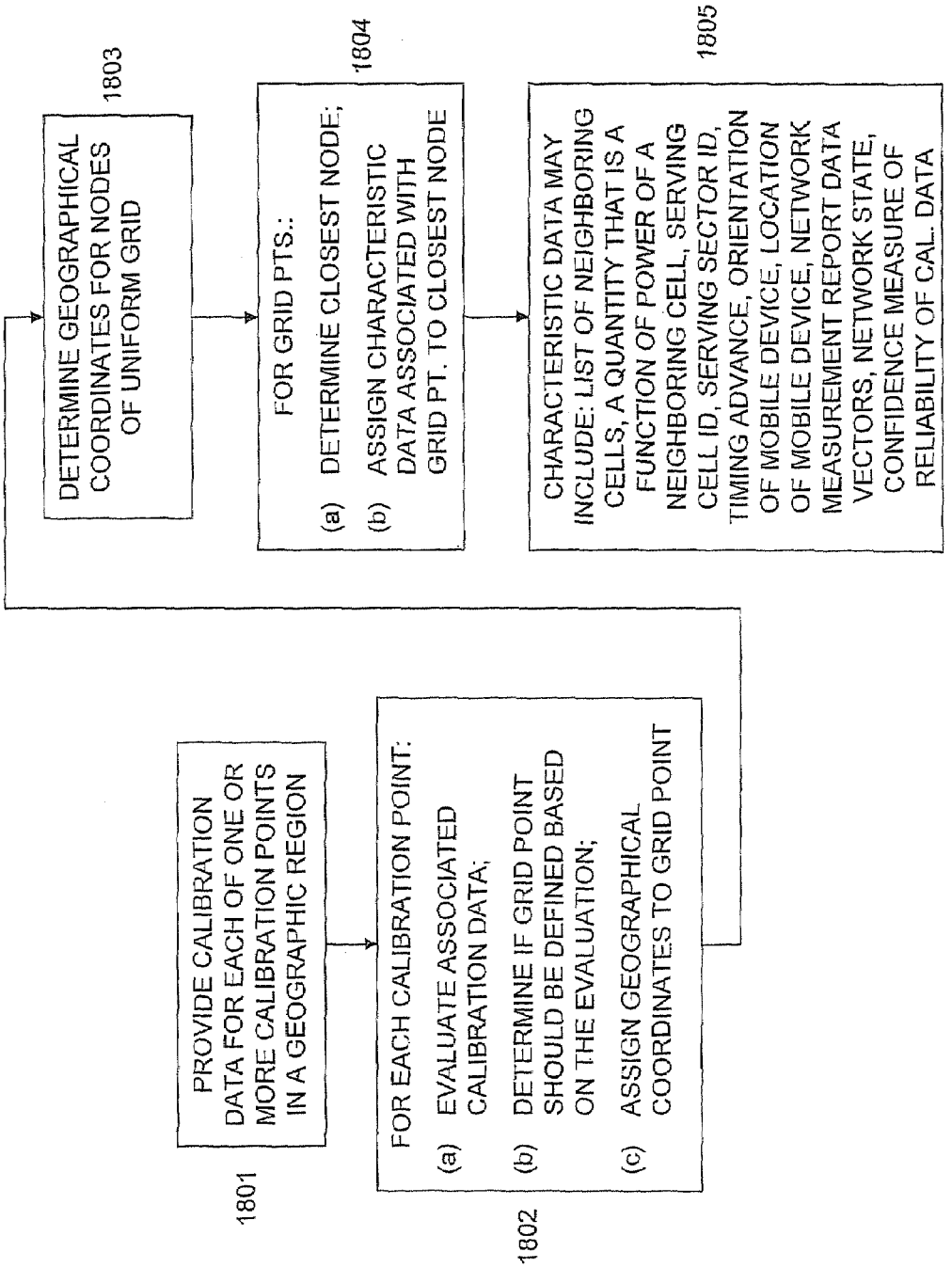

1801
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1802
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1803
DETERMINE GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
1804
FOR GRID PTS.:
(a) DETERMINE CLOSEST NODE;
(b) ASSIGN CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
1805
CHARACTERISTIC DATA MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA

FIGURE 18

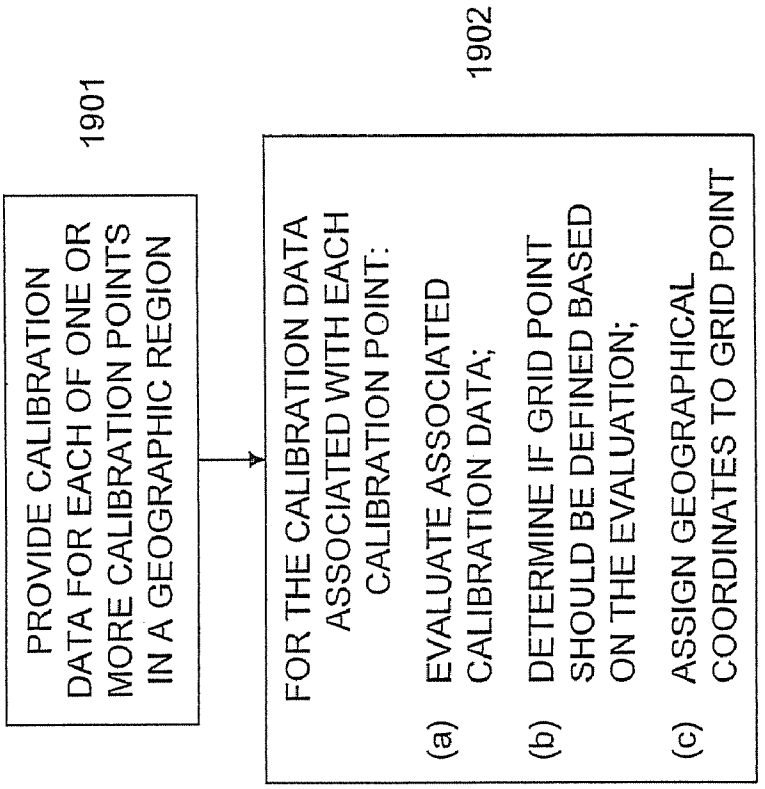

1901
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1902
FOR THE CALIBRATION DATA ASSOCIATED WITH EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT

FIGURE 19

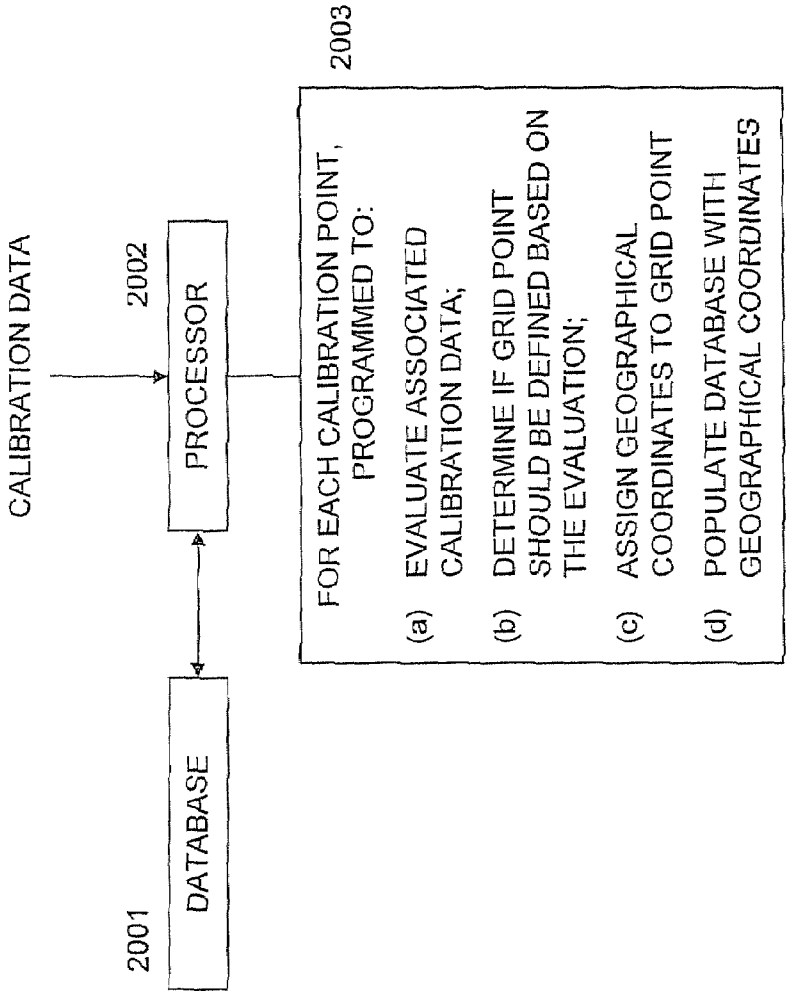

CALIBRATION DATA
2002
PROCESSOR
2001
DATABASE
2003
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES

FIGURE 20

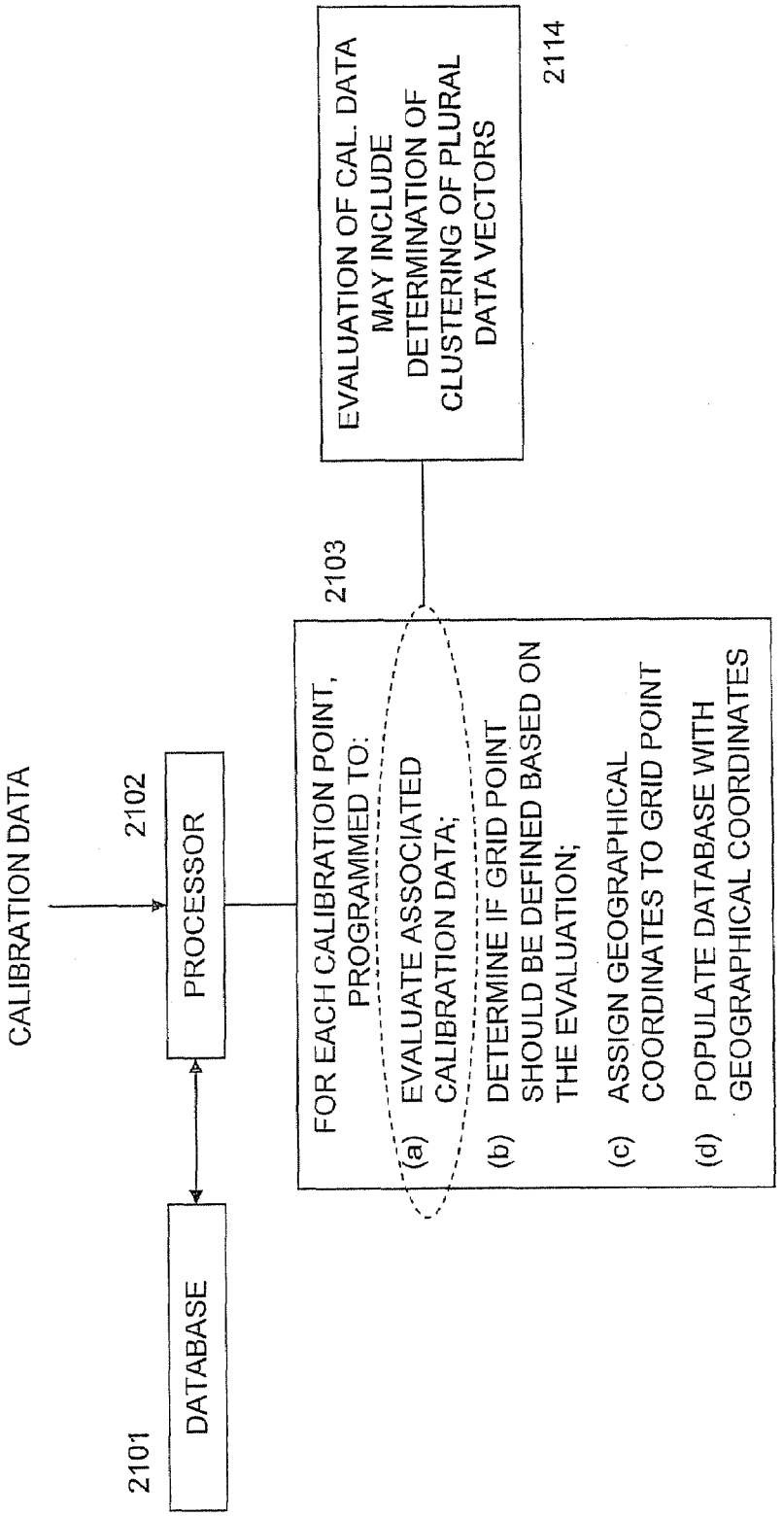

CALIBRATION DATA
2102
PROCESSOR
2101
DATABASE
2103
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
2114

FIGURE 21

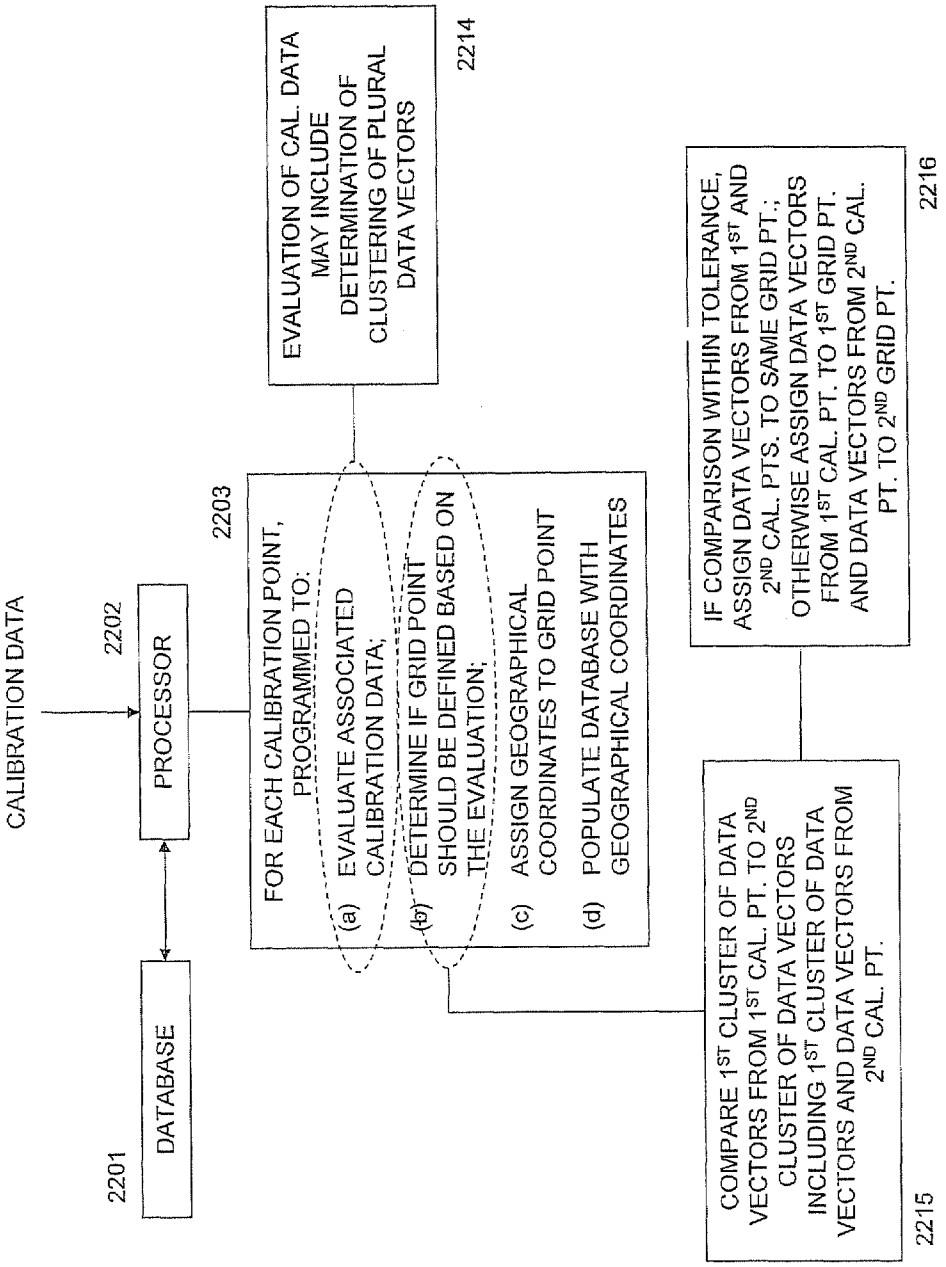

CALIBRATION DATA
2202
PROCESSOR
2201
DATABASE
2203
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
2214
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS INCLUDING 1ST CLUSTER OF DATA VECTORS AND DATA VECTORS FROM 2ND CAL. PT.
2215
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CAL. PTS. TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CAL. PT. TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CAL. PT. TO 2ND GRID PT.
2216

FIGURE 22

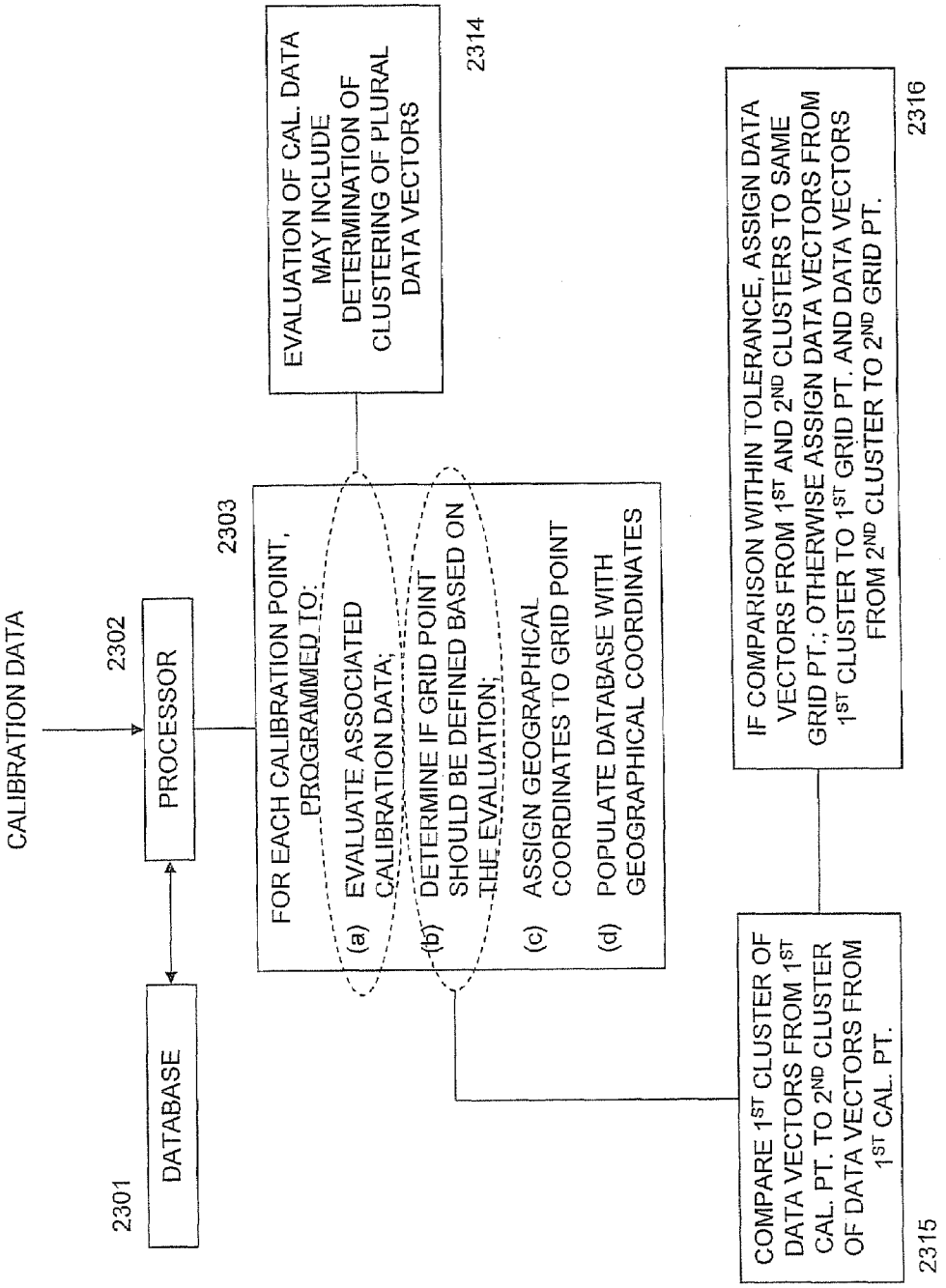

CALIBRATION DATA
2302
PROCESSOR
2301
DATABASE
2303
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2314
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
2315
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
2316
IF COMPARISON WITHIN TOLERANCE, ASSIGN DATA VECTORS FROM 1ST AND 2ND CLUSTERS TO SAME GRID PT.; OTHERWISE ASSIGN DATA VECTORS FROM 1ST CLUSTER TO 1ST GRID PT. AND DATA VECTORS FROM 2ND CLUSTER TO 2ND GRID PT.

FIGURE 23

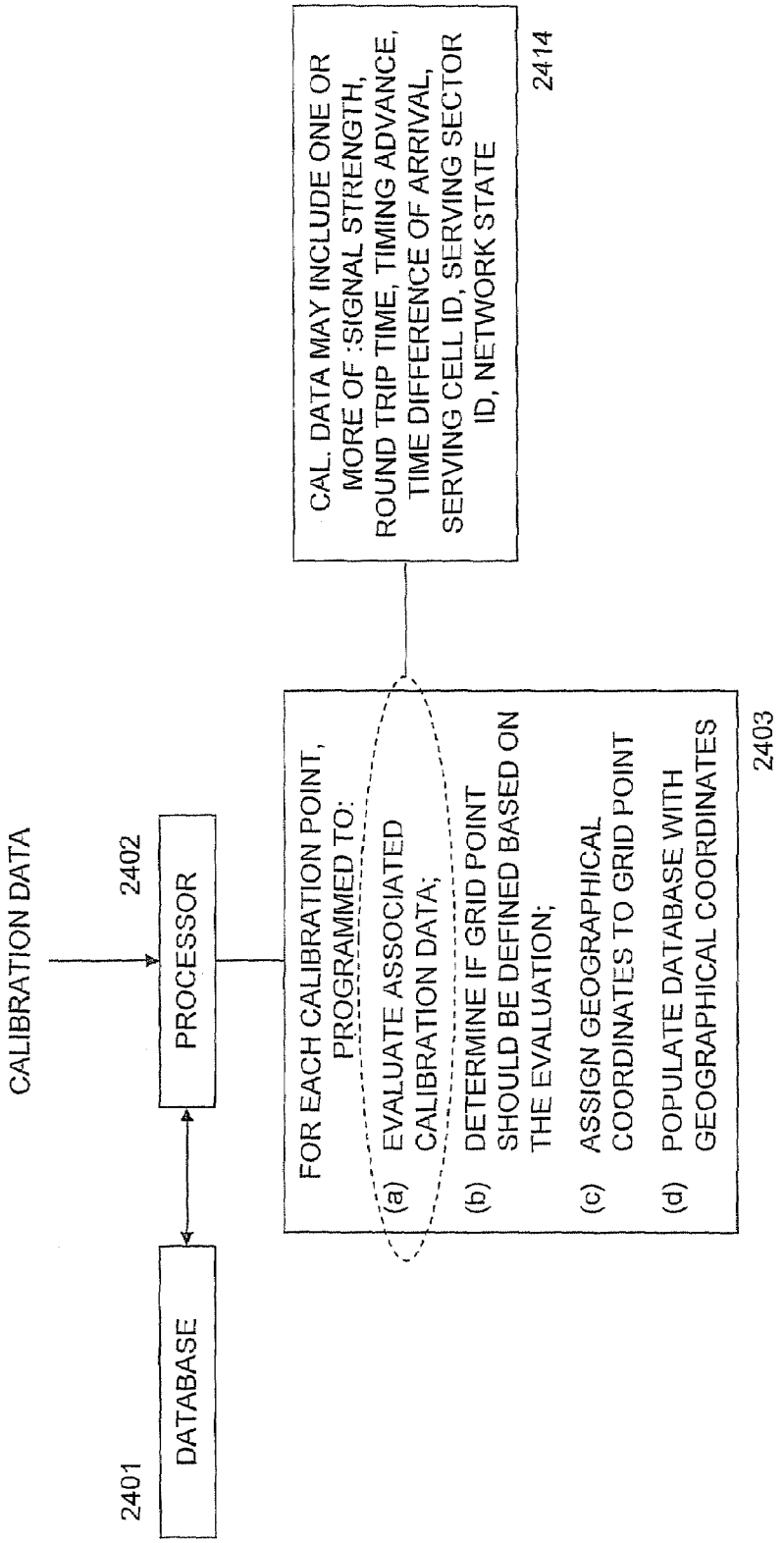

CALIBRATION DATA
2402
PROCESSOR
2401
DATABASE
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2403
CAL. DATA MAY INCLUDE ONE OR MORE OF :SIGNAL STRENGTH, ROUND TRIP TIME, TIMING ADVANCE, TIME DIFFERENCE OF ARRIVAL, SERVING CELL ID, SERVING SECTOR ID, NETWORK STATE
2414

FIGURE 24

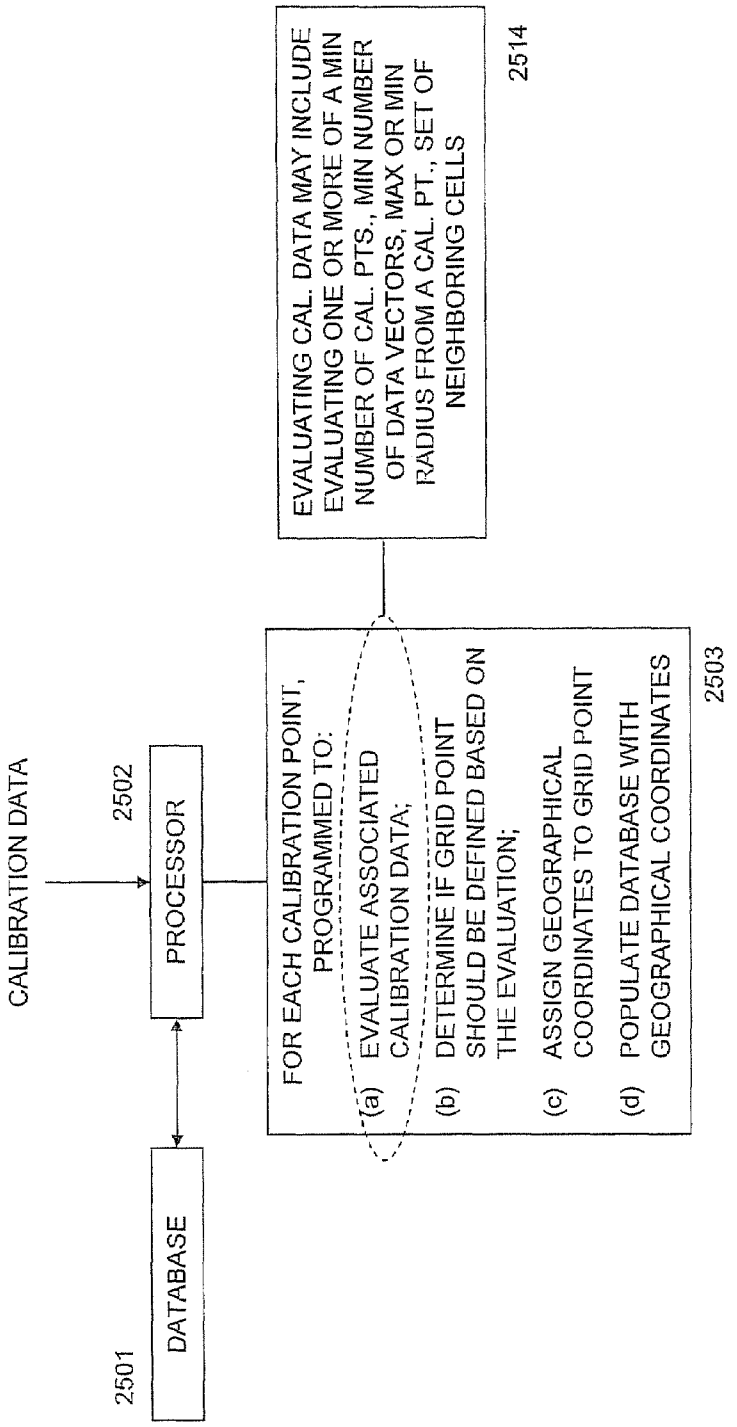

CALIBRATION DATA
2502
PROCESSOR
2501
DATABASE
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2503
EVALUATING CAL. DATA MAY INCLUDE EVALUATING ONE OR MORE OF A MIN NUMBER OF CAL. PTS., MIN NUMBER OF DATA VECTORS, MAX OR MIN RADIUS FROM A CAL. PT., SET OF NEIGHBORING CELLS
2514

FIGURE 25

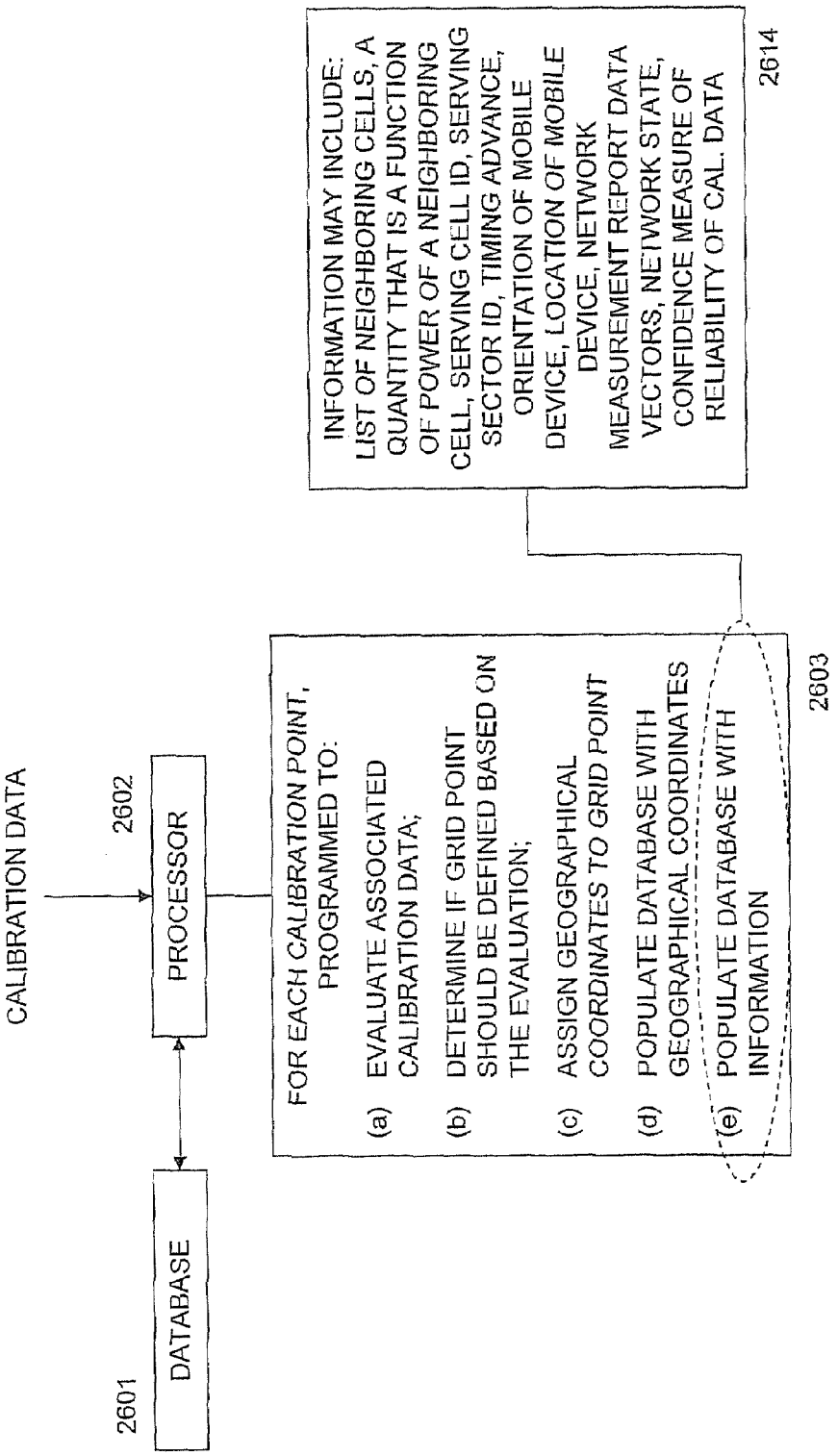

CALIBRATION DATA
2602
PROCESSOR
2601
DATABASE
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2603
INFORMATION MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA
2614

FIGURE 26

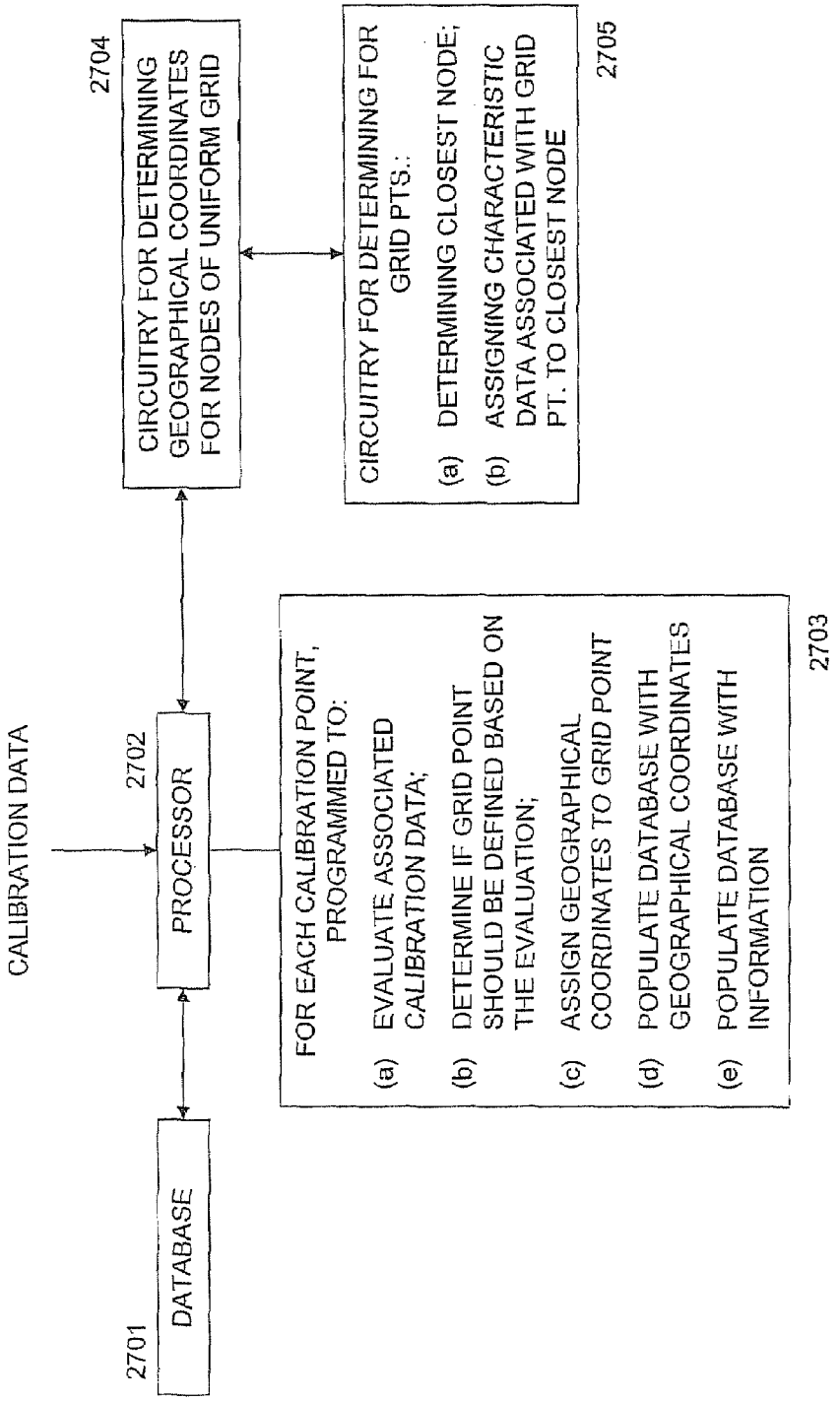

CALIBRATION DATA
2701
DATABASE
2702
PROCESSOR
2703
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2704
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
2705
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE

FIGURE 27

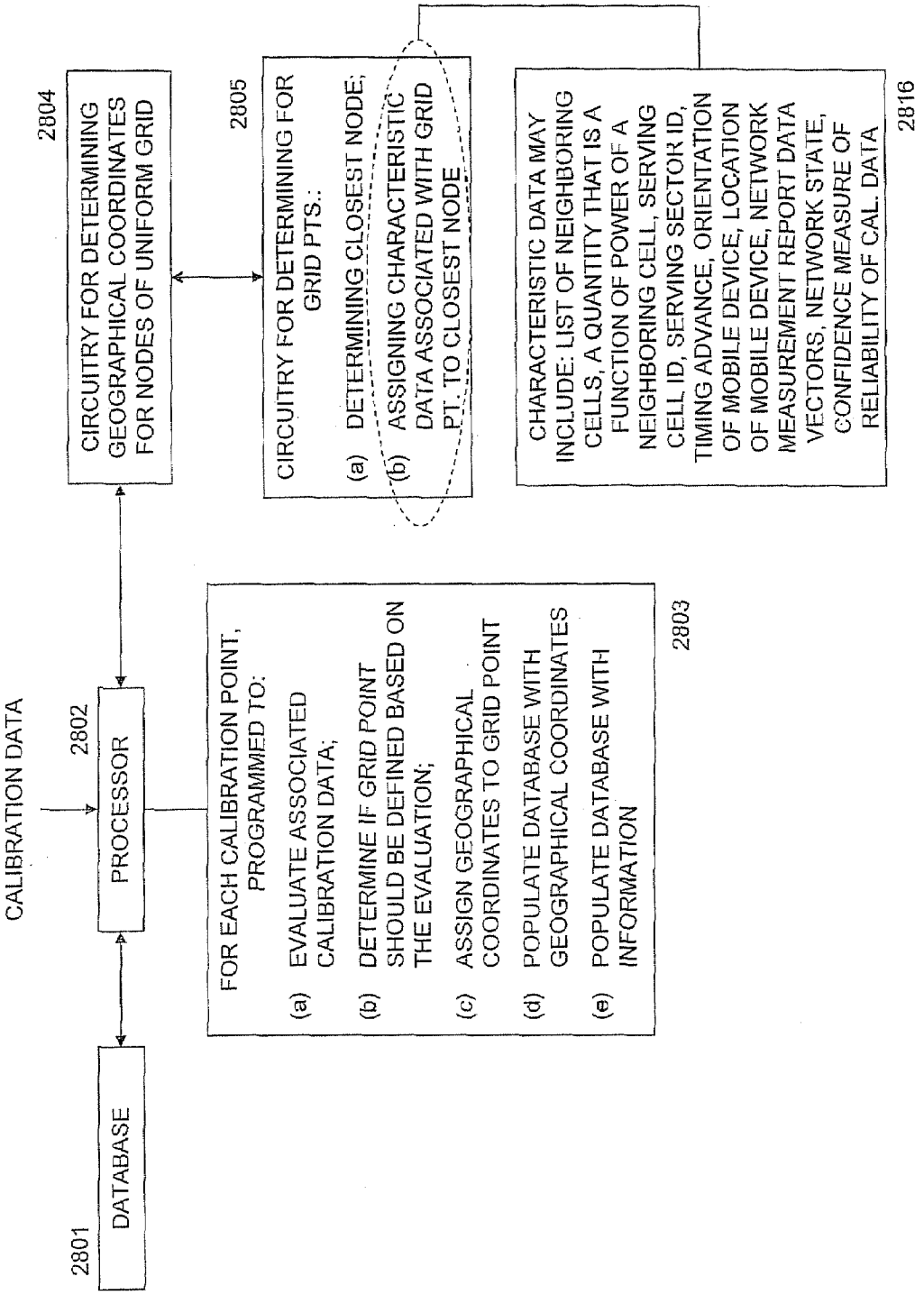

CALIBRATION DATA
2801
DATABASE
2802
PROCESSOR
2804
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
2805
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
2816
CHARACTERISTIC DATA MAY INCLUDE: LIST OF NEIGHBORING CELLS, A QUANTITY THAT IS A FUNCTION OF POWER OF A NEIGHBORING CELL, SERVING CELL ID, SERVING SECTOR ID, TIMING ADVANCE, ORIENTATION OF MOBILE DEVICE, LOCATION OF MOBILE DEVICE, NETWORK MEASUREMENT REPORT DATA VECTORS, NETWORK STATE, CONFIDENCE MEASURE OF RELIABILITY OF CAL. DATA
2803
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION

FIGURE 28

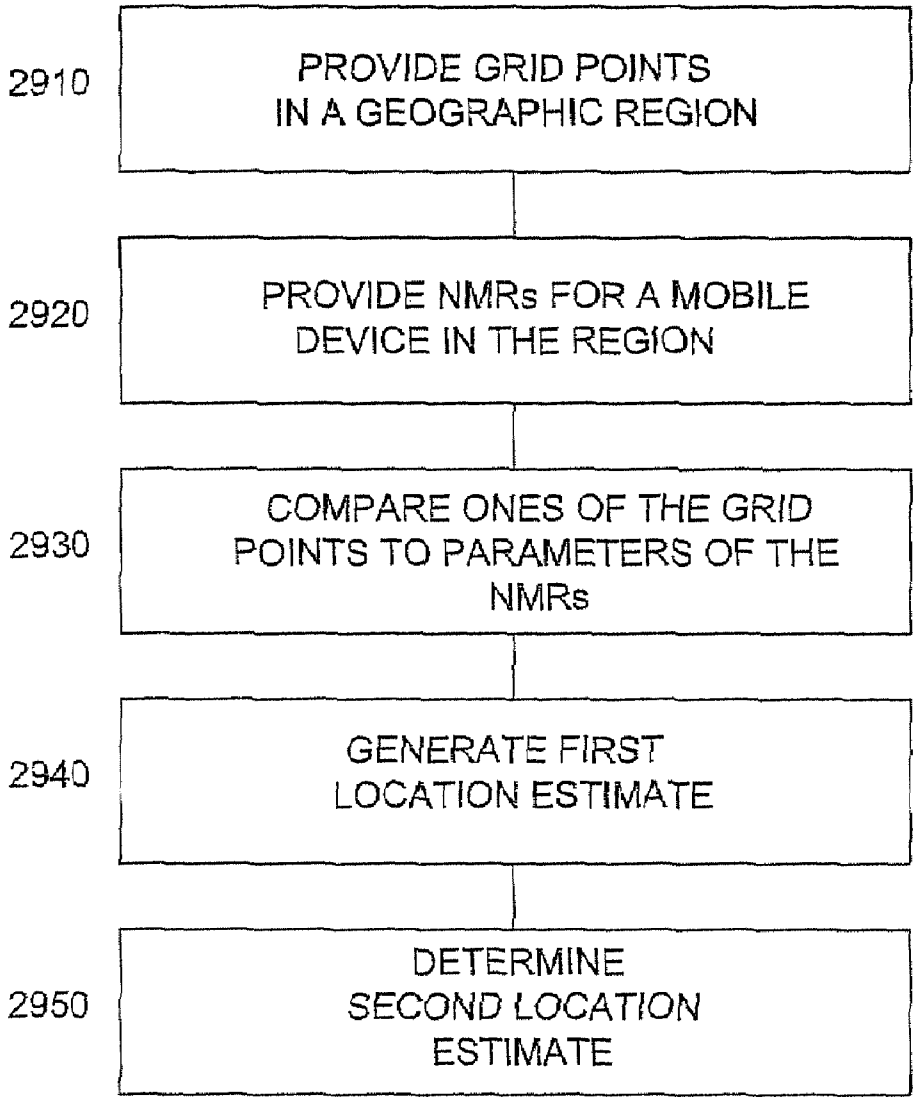

2910
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
2920
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
2930
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
2940
GENERATE FIRST LOCATION ESTIMATE
2950
DETERMINE SECOND LOCATION ESTIMATE

FIG. 29

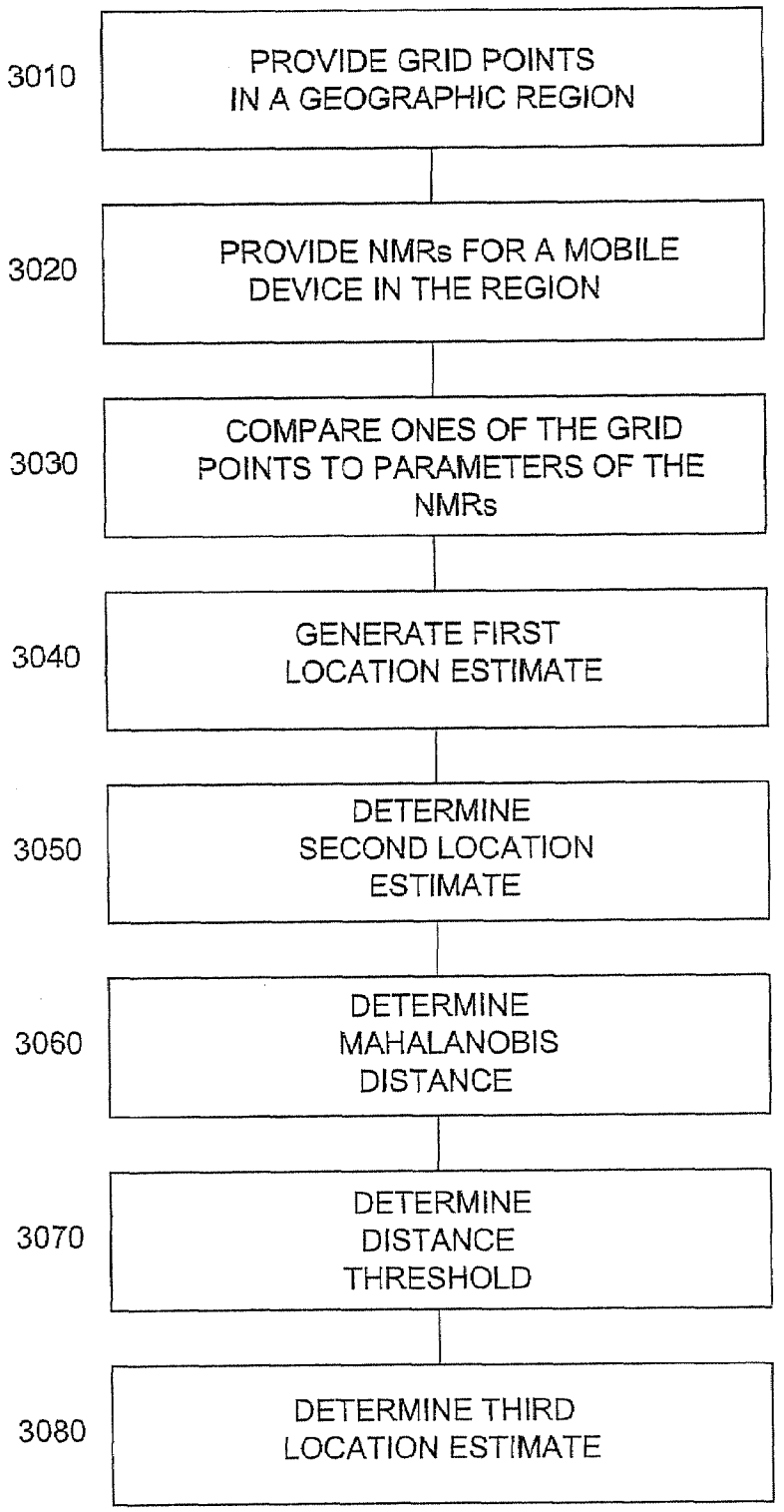

3010
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3020
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3030
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3040
GENERATE FIRST LOCATION ESTIMATE
3050
DETERMINE SECOND LOCATION ESTIMATE
3060
DETERMINE MAHALANOBIS DISTANCE
3070
DETERMINE DISTANCE THRESHOLD
3080
DETERMINE THIRD LOCATION ESTIMATE

FIG. 30

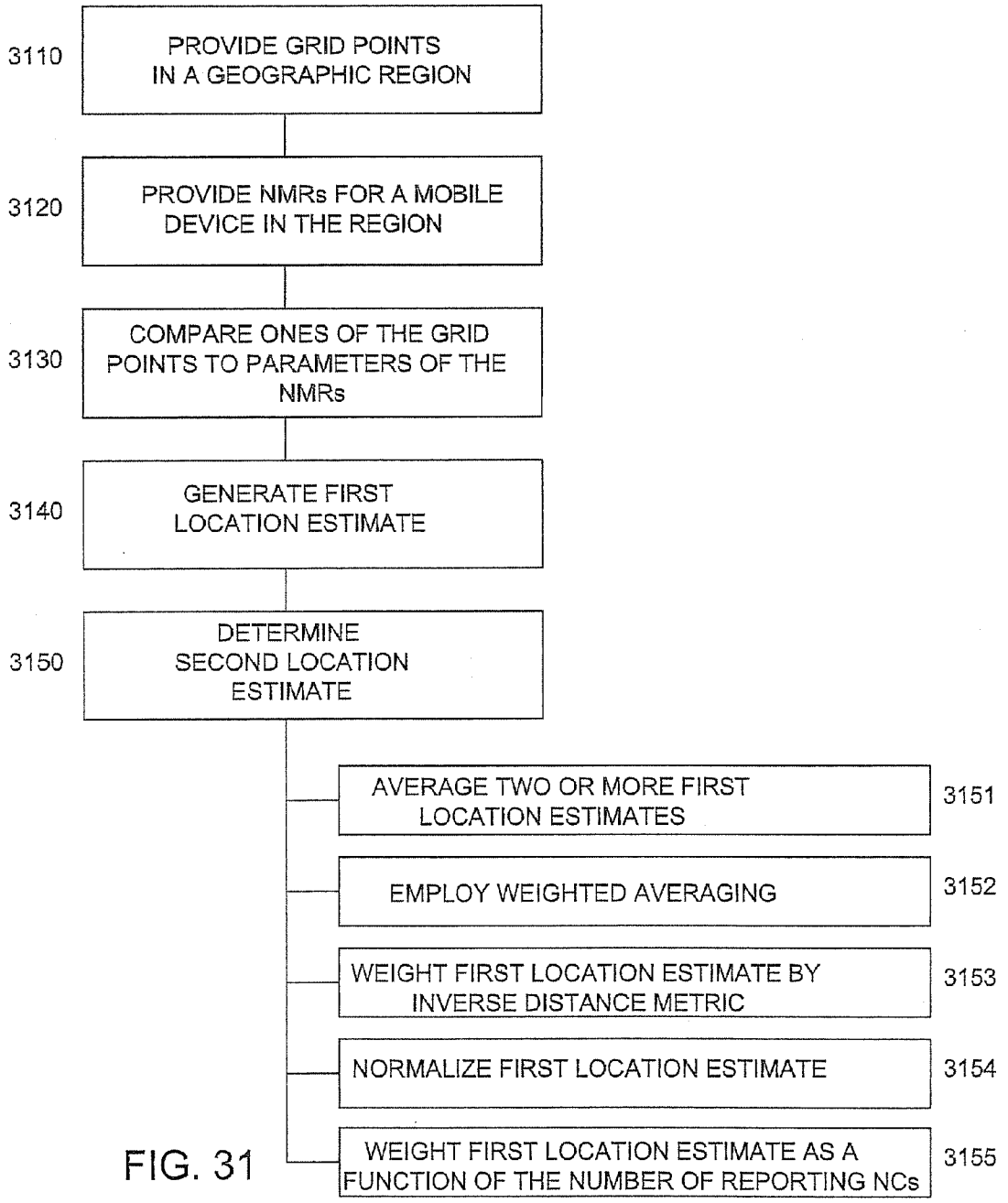

3110
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3120
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3130
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3140
GENERATE FIRST LOCATION ESTIMATE
3150
DETERMINE SECOND LOCATION ESTIMATE
AVERAGE TWO OR MORE FIRST LOCATION ESTIMATES
3151
EMPLOY WEIGHTED AVERAGING
3152
WEIGHT FIRST LOCATION ESTIMATE BY INVERSE DISTANCE METRIC
3153
NORMALIZE FIRST LOCATION ESTIMATE
3154
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF THE NUMBER OF REPORTING NCs
3155

FIG. 31

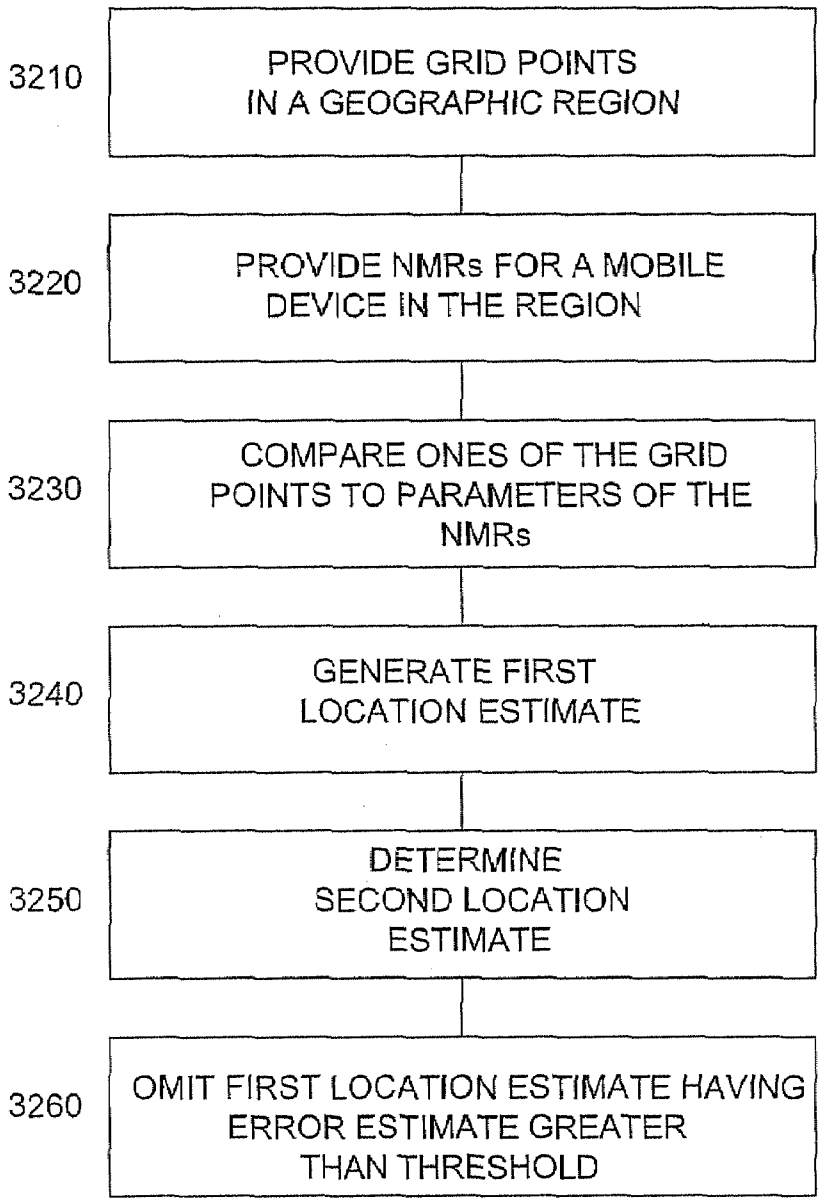

3210
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3220
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3230
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3240
GENERATE FIRST LOCATION ESTIMATE
3250
DETERMINE SECOND LOCATION ESTIMATE
3260
OMIT FIRST LOCATION ESTIMATE HAVING ERROR ESTIMATE GREATER THAN THRESHOLD

FIG. 32

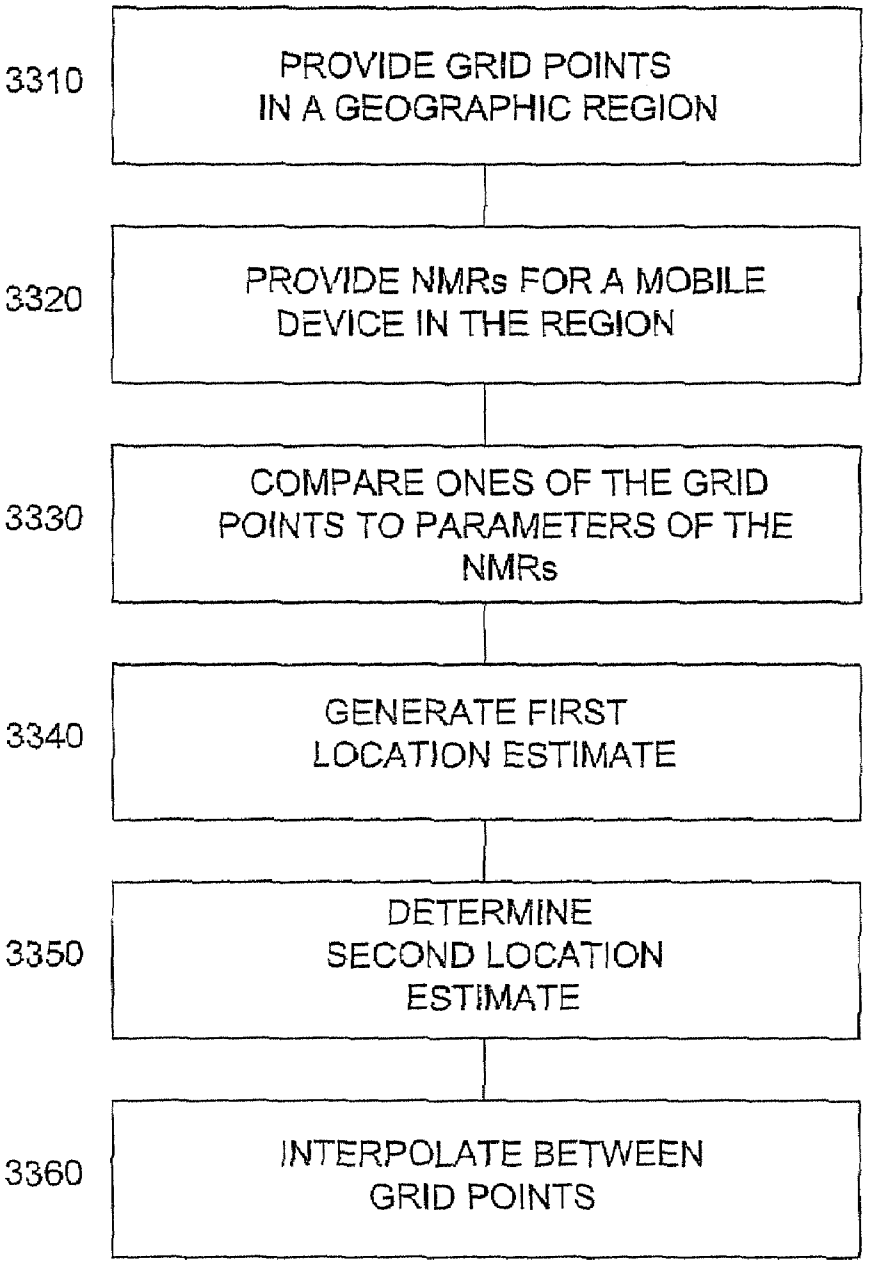

3310
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3320
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3330
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3340
GENERATE FIRST LOCATION ESTIMATE
3350
DETERMINE SECOND LOCATION ESTIMATE
3360
INTERPOLATE BETWEEN GRID POINTS

FIG. 33

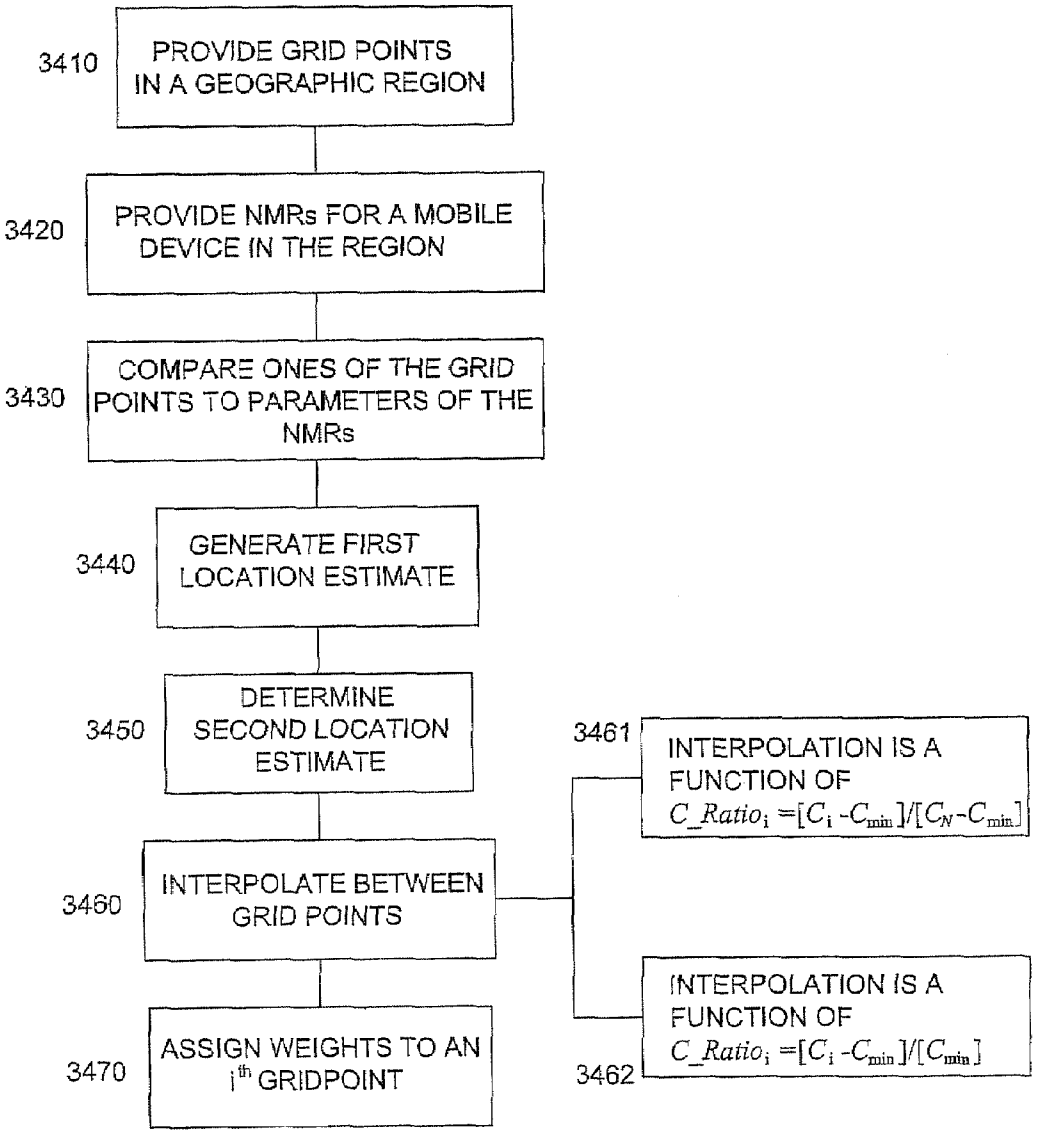

3410
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3420
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3430
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3440
GENERATE FIRST LOCATION ESTIMATE
3450
DETERMINE SECOND LOCATION ESTIMATE
3460
INTERPOLATE BETWEEN GRID POINTS
3470
ASSIGN WEIGHTS TO AN $i^{th}$ GRIDPOINT
3461
INTERPOLATION IS A FUNCTION OF $C\_Ratio_i = [C_i - C_{min}]/[C_N - C_{min}]$
3462
INTERPOLATION IS A FUNCTION OF $C\_Ratio_i = [C_i - C_{min}]/[C_{min}]$

FIG. 34

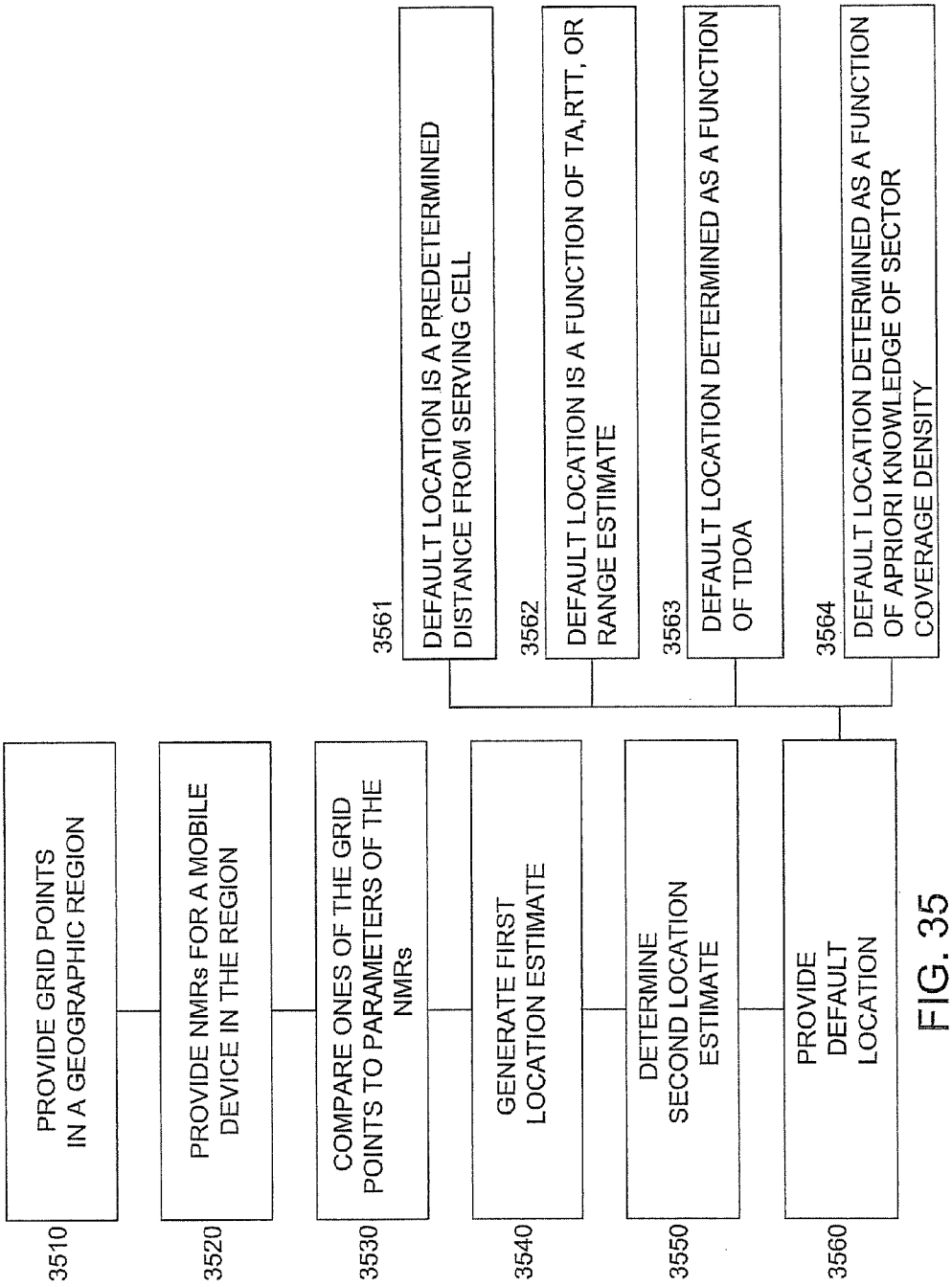

3510
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3520
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3530
COMPARE ONES OF THE GRID POINTS TO PARAMETERS OF THE NMRs
3540
GENERATE FIRST LOCATION ESTIMATE
3550
DETERMINE SECOND LOCATION ESTIMATE
3560
PROVIDE DEFAULT LOCATION
3561
DEFAULT LOCATION IS A PREDETERMINED DISTANCE FROM SERVING CELL
3562
DEFAULT LOCATION IS A FUNCTION OF TA,RTT, OR RANGE ESTIMATE
3563
DEFAULT LOCATION DETERMINED AS A FUNCTION OF TDOA
3564
DEFAULT LOCATION DETERMINED AS A FUNCTION OF APRIORI KNOWLEDGE OF SECTOR COVERAGE DENSITY

FIG. 35

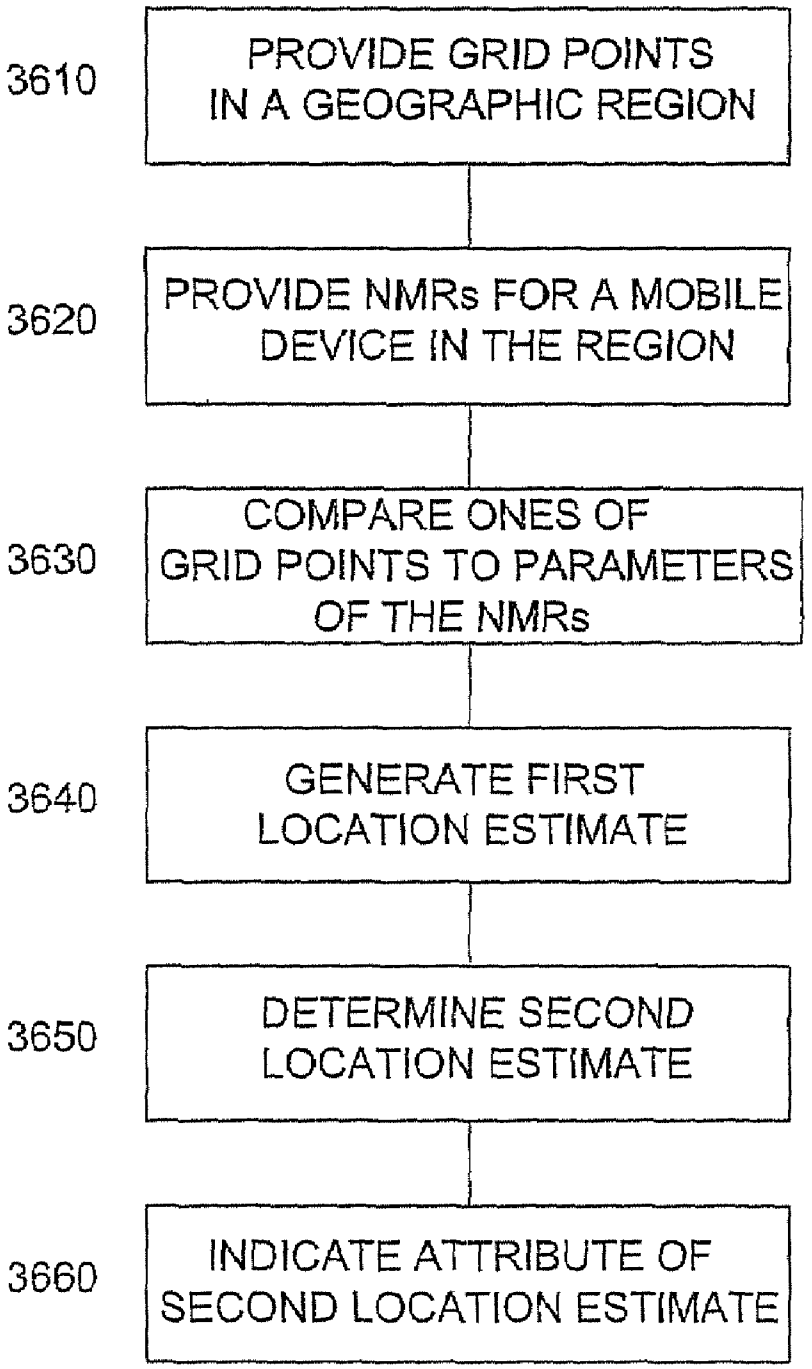

3610
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3620
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3630
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3640
GENERATE FIRST LOCATION ESTIMATE
3650
DETERMINE SECOND LOCATION ESTIMATE
3660
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE

FIG. 36

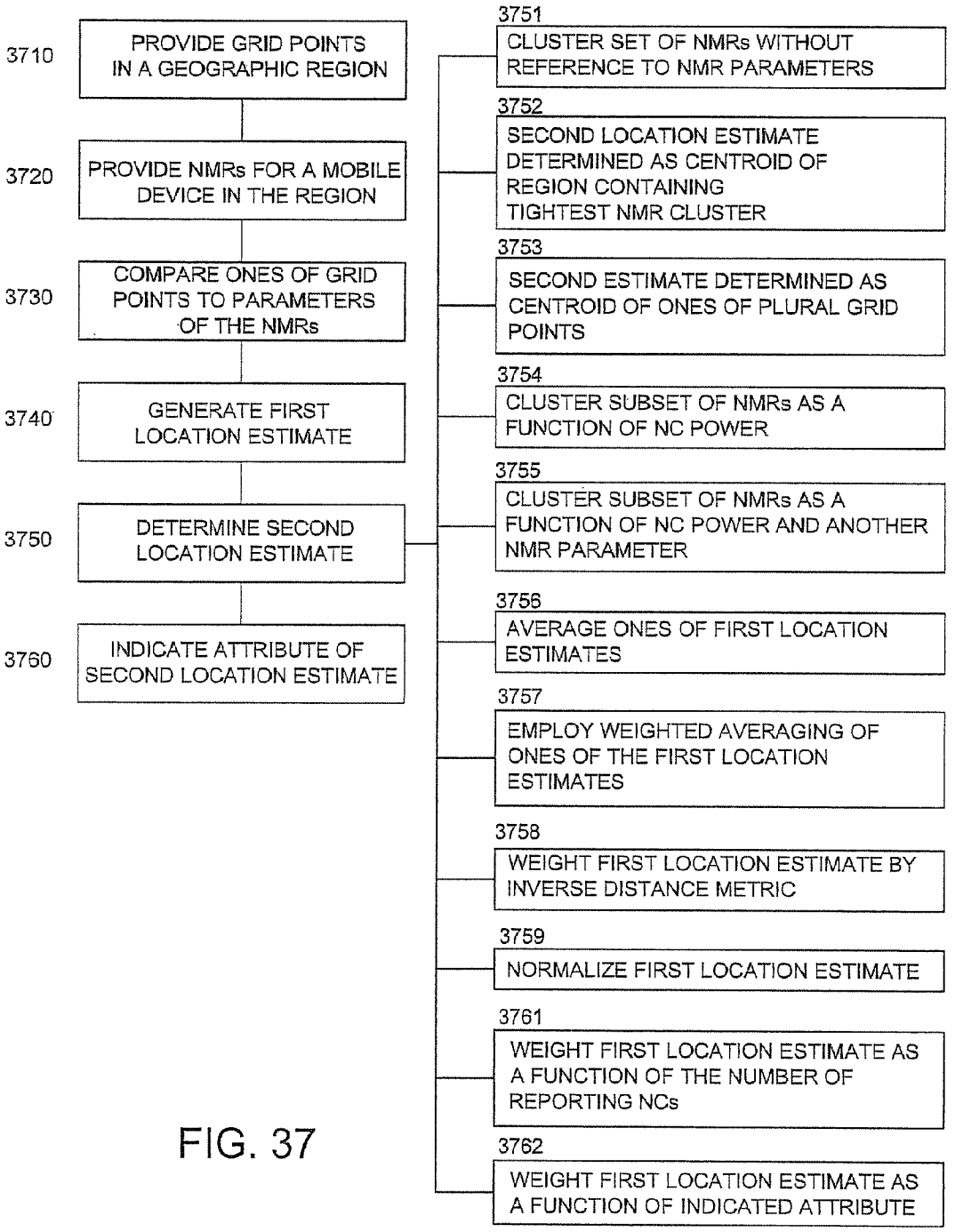

3710
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3720
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3730
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3740
GENERATE FIRST LOCATION ESTIMATE
3750
DETERMINE SECOND LOCATION ESTIMATE
3760
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3751
CLUSTER SET OF NMRs WITHOUT REFERENCE TO NMR PARAMETERS
3752
SECOND LOCATION ESTIMATE DETERMINED AS CENTROID OF REGION CONTAINING TIGHTEST NMR CLUSTER
3753
SECOND ESTIMATE DETERMINED AS CENTROID OF ONES OF PLURAL GRID POINTS
3754
CLUSTER SUBSET OF NMRs AS A FUNCTION OF NC POWER
3755
CLUSTER SUBSET OF NMRs AS A FUNCTION OF NC POWER AND ANOTHER NMR PARAMETER
3756
AVERAGE ONES OF FIRST LOCATION ESTIMATES
3757
EMPLOY WEIGHTED AVERAGING OF ONES OF THE FIRST LOCATION ESTIMATES
3758
WEIGHT FIRST LOCATION ESTIMATE BY INVERSE DISTANCE METRIC
3759
NORMALIZE FIRST LOCATION ESTIMATE
3761
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF THE NUMBER OF REPORTING NCs
3762
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF INDICATED ATTRIBUTE

FIG. 37

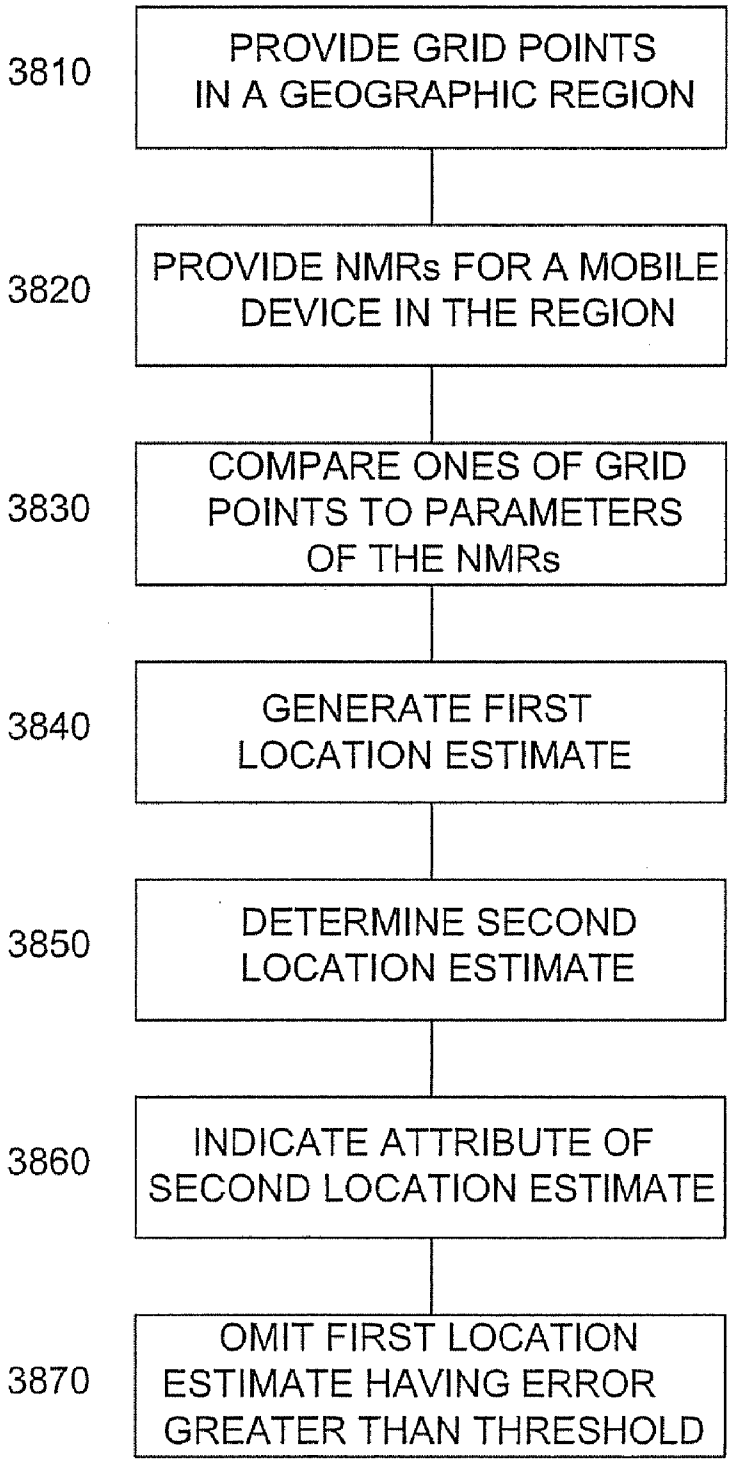

3810
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3820
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3830
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3840
GENERATE FIRST LOCATION ESTIMATE
3850
DETERMINE SECOND LOCATION ESTIMATE
3860
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3870
OMIT FIRST LOCATION ESTIMATE HAVING ERROR GREATER THAN THRESHOLD

FIG. 38

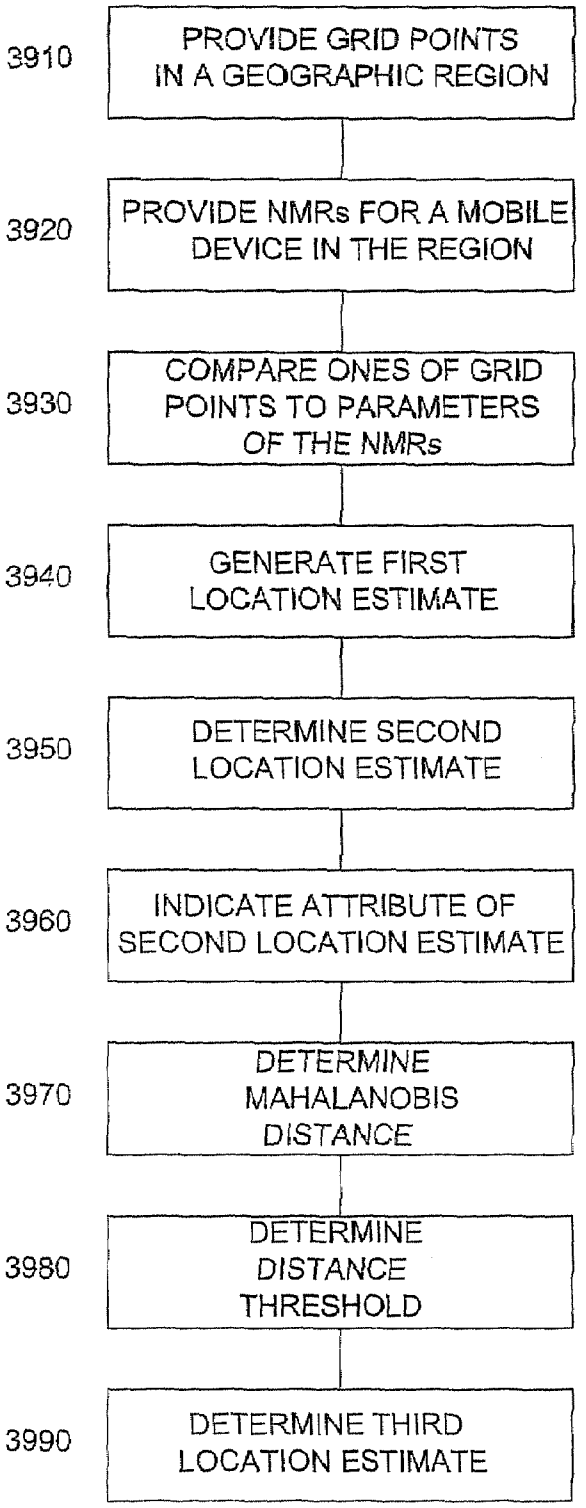

3910
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
3920
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
3930
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
3940
GENERATE FIRST LOCATION ESTIMATE
3950
DETERMINE SECOND LOCATION ESTIMATE
3960
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
3970
DETERMINE MAHALANOBIS DISTANCE
3980
DETERMINE DISTANCE THRESHOLD
3990
DETERMINE THIRD LOCATION ESTIMATE

FIG. 39

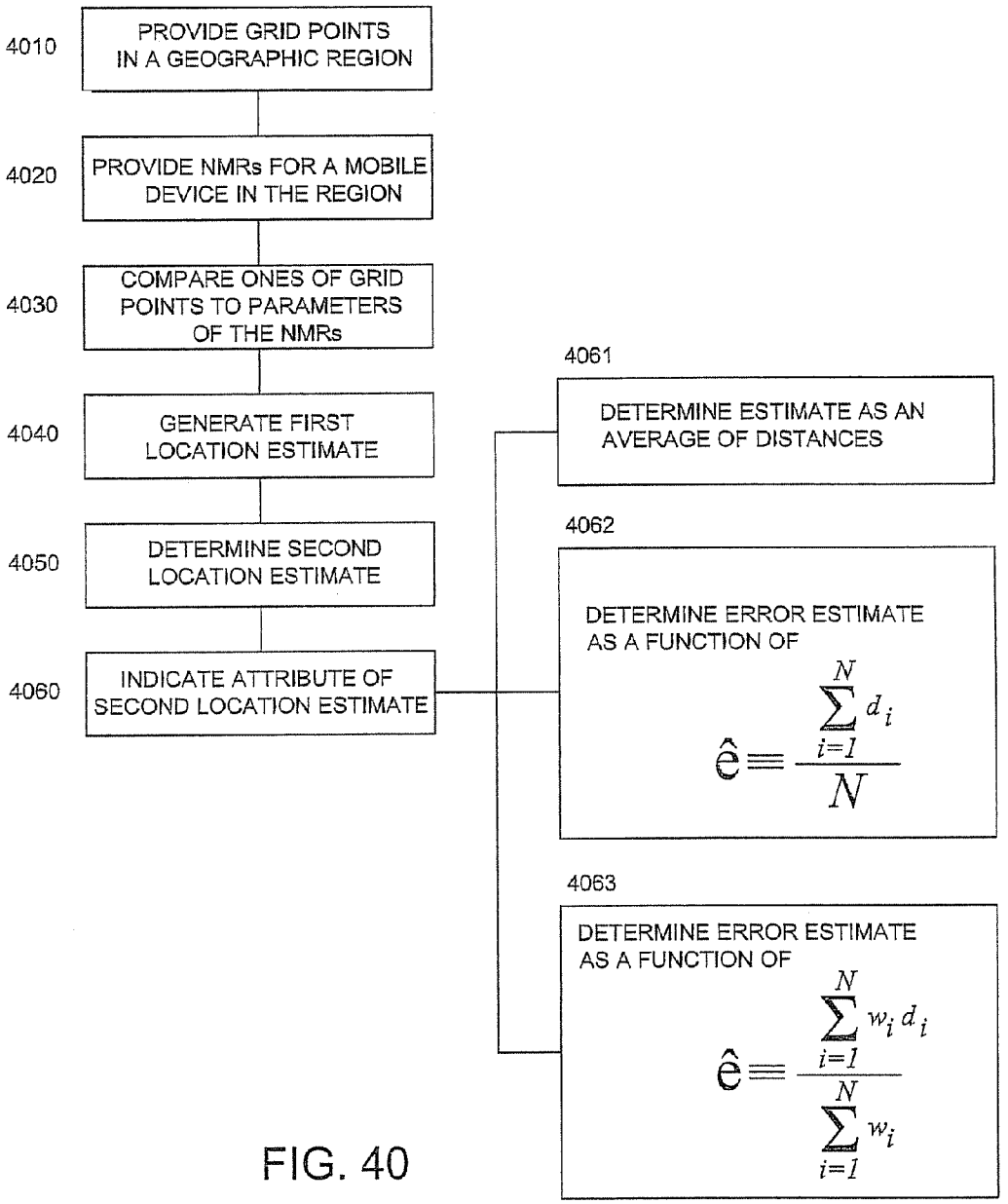
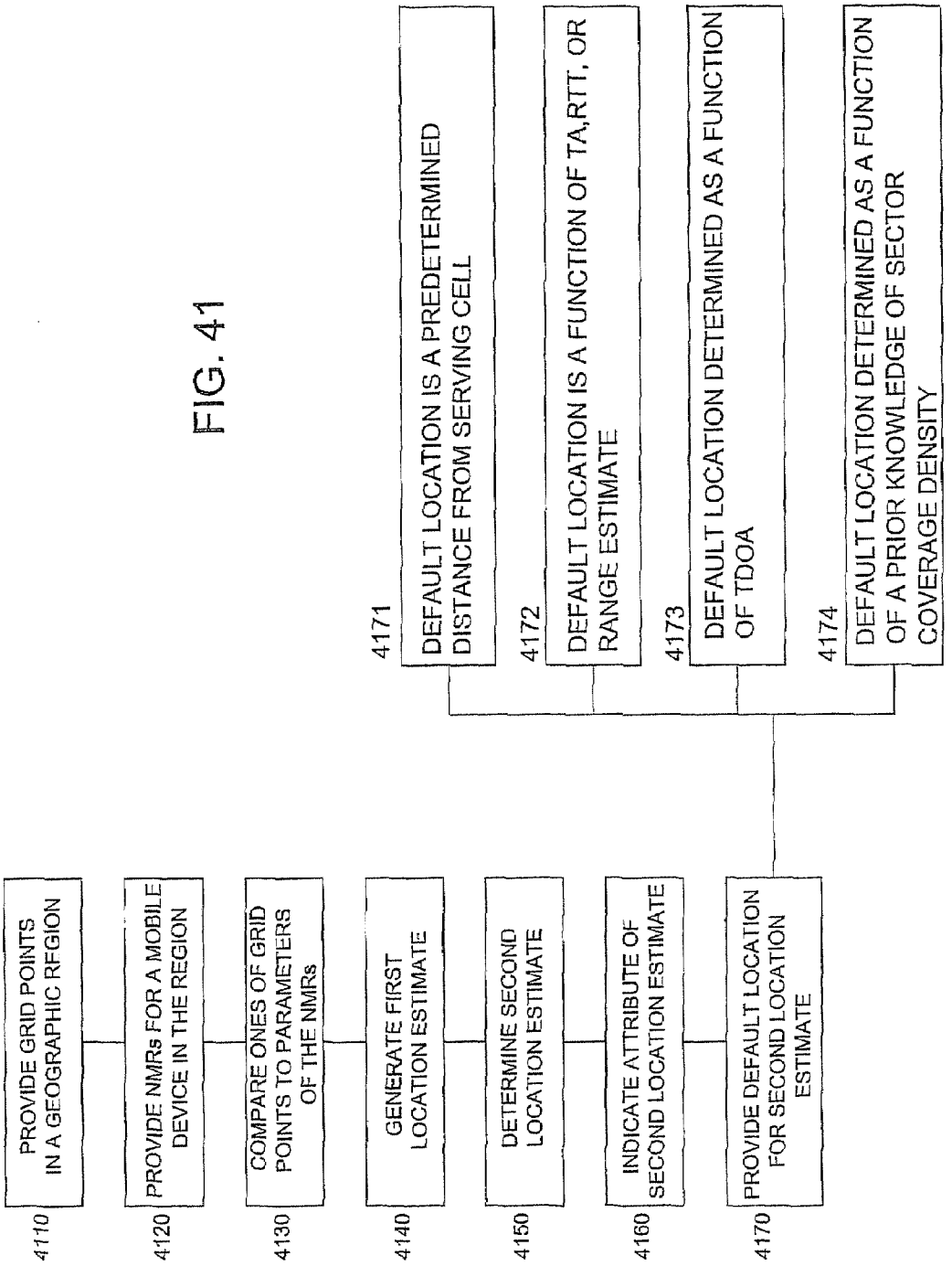

4010
PROVIDE GRID POINTS IN A GEOGRAPHIC REGION
4020
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
4030
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
4040
GENERATE FIRST LOCATION ESTIMATE
4050
DETERMINE SECOND LOCATION ESTIMATE
4060
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
4061
DETERMINE ESTIMATE AS AN AVERAGE OF DISTANCES
4062
DETERMINE ERROR ESTIMATE AS A FUNCTION OF
$\hat{e} \equiv \frac{\sum_{i=1}^{N} d_i}{N}$
4063
DETERMINE ERROR ESTIMATE AS A FUNCTION OF
$\hat{e} \equiv \frac{\sum_{i=1}^{N} w_i d_i}{\sum_{i=1}^{N} w_i}$

FIG. 40

FIG. 41


4110
PROVIDE GRID POINTS IN A GEOGRAPHIC RFGION
4120
PROVIDE NMRs FOR A MOBILE DEVICE IN THE REGION
4130
COMPARE ONES OF GRID POINTS TO PARAMETERS OF THE NMRs
4140
GENERATE FIRST LOCATION ESTIMATE
4150
DETERMINE SECOND LOCATION ESTIMATE
4160
INDICATE ATTRIBUTE OF SECOND LOCATION ESTIMATE
4170
PROVIDE DEFAULT LOCATION FOR SECOND LOCATION ESTIMATE
4171
DEFAULT LOCATION IS A PREDETERMINED DISTANCE FROM SERVING CELL
4172
DEFAULT LOCATION IS A FUNCTION OF TA,RTT, OR RANGE ESTIMATE
4173
DEFAULT LOCATION DETERMINED AS A FUNCTION OF TDOA
4174
DEFAULT LOCATION DETERMINED AS A FUNCTION OF A PRIOR KNOWLEDGE OF SECTOR COVERAGE DENSITY

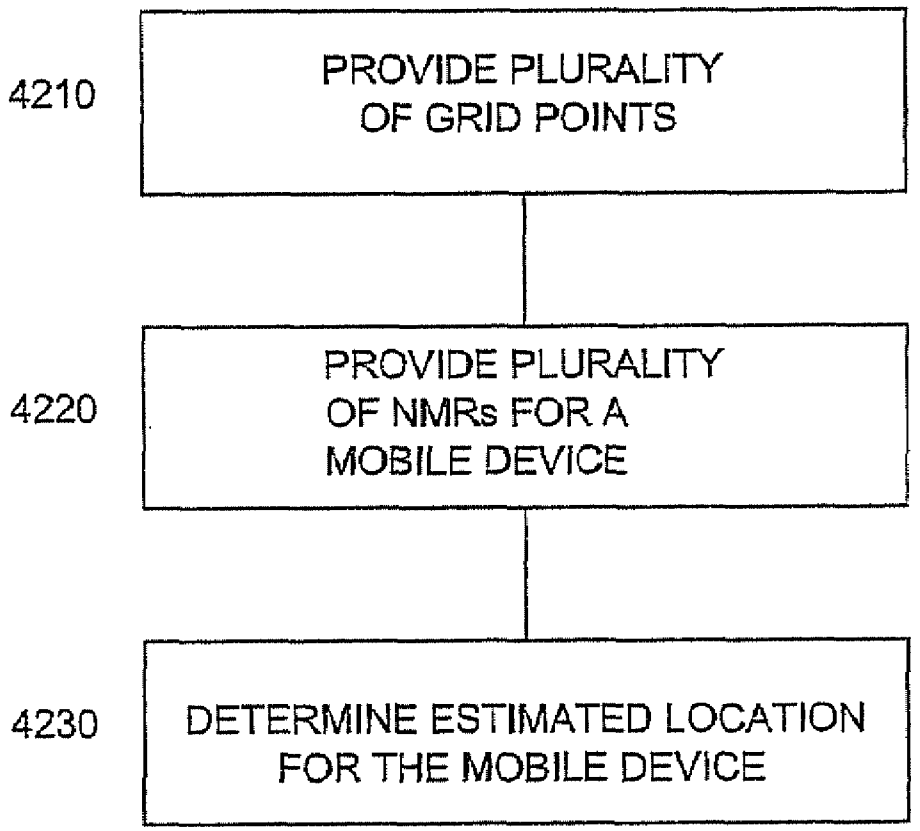

4210
PROVIDE PLURALITY OF GRID POINTS
4220
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4230
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE

FIG. 42

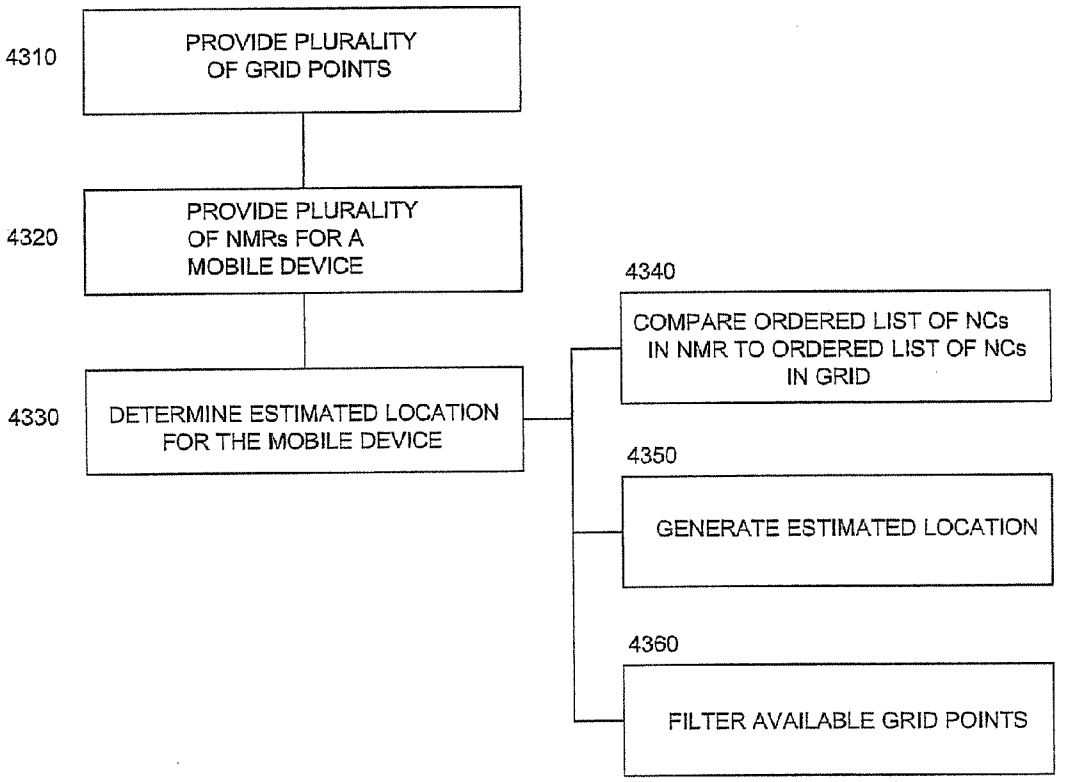

4310
PROVIDE PLURALITY OF GRID POINTS
4320
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4330
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4340
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4350
GENERATE ESTIMATED LOCATION
4360
FILTER AVAILABLE GRID POINTS

FIG. 43

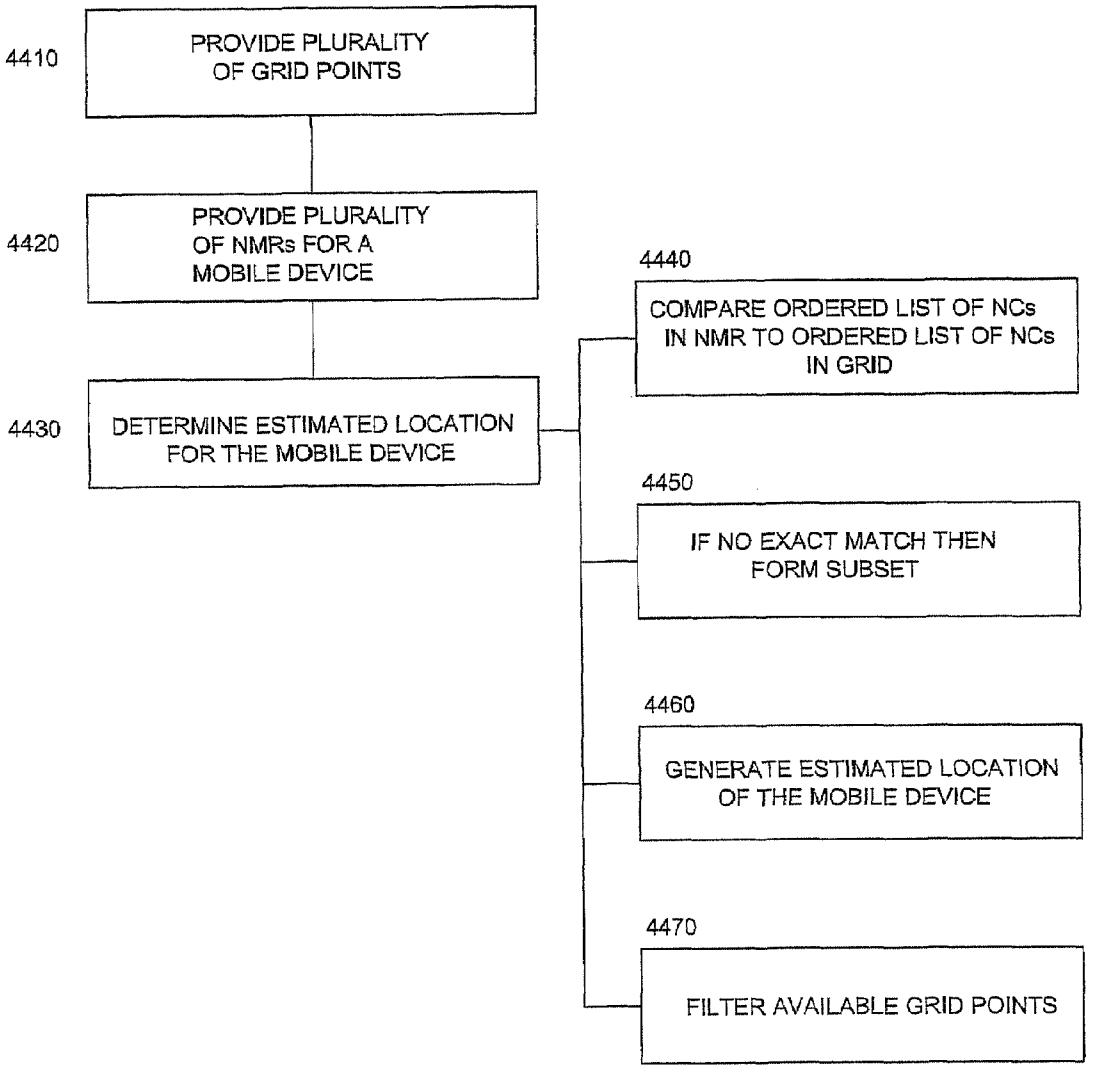

4410
PROVIDE PLURALITY OF GRID POINTS
4420
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4430
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4440
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4450
IF NO EXACT MATCH THEN FORM SUBSET
4460
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4470
FILTER AVAILABLE GRID POINTS

FIG. 44

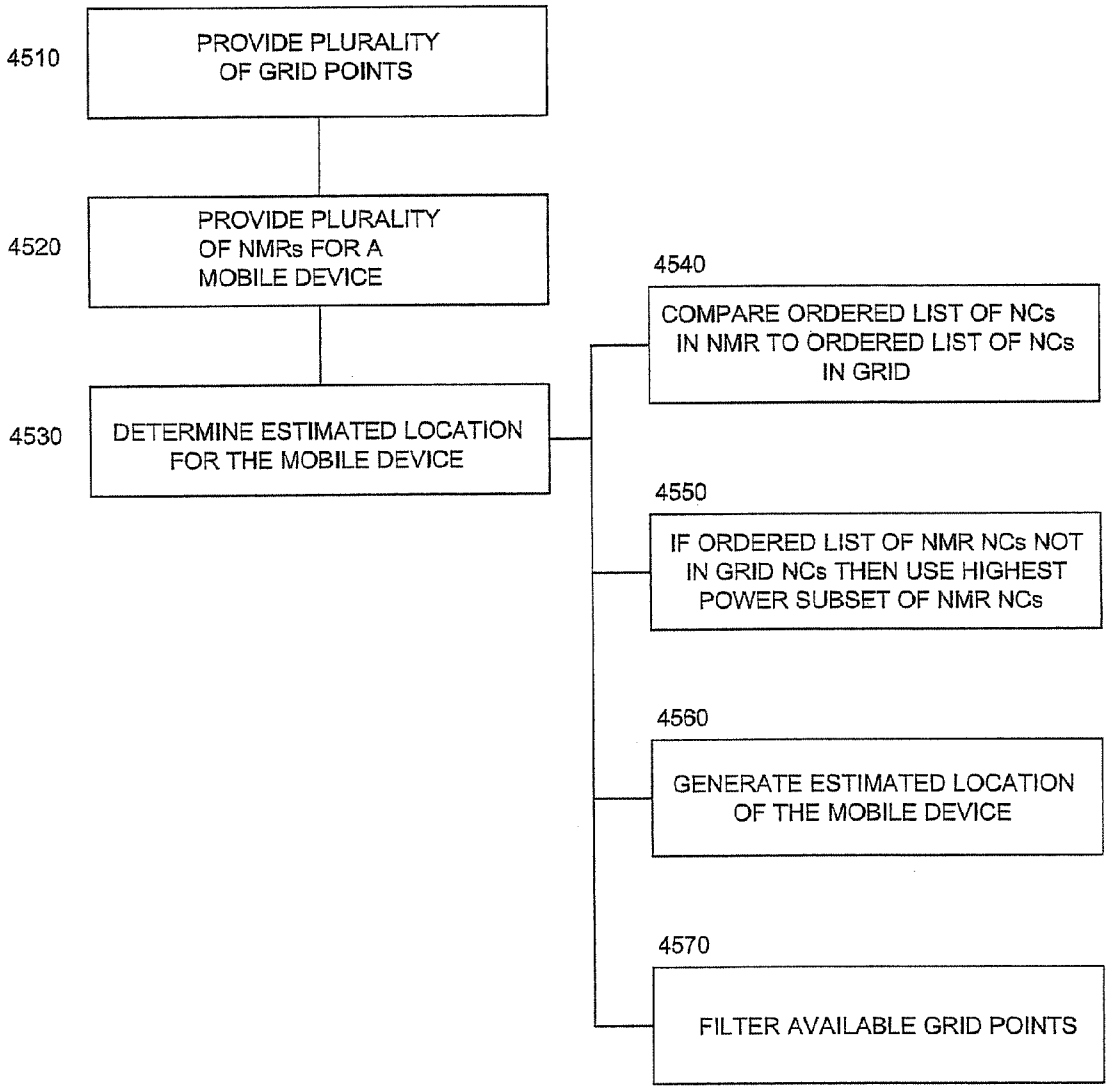

4510
PROVIDE PLURALITY OF GRID POINTS
4520
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4530
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4540
COMPARE ORDERED LIST OF NCs IN NMR TO ORDERED LIST OF NCs IN GRID
4550
IF ORDERED LIST OF NMR NCs NOT IN GRID NCs THEN USE HIGHEST POWER SUBSET OF NMR NCs
4560
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4570
FILTER AVAILABLE GRID POINTS

FIG. 45

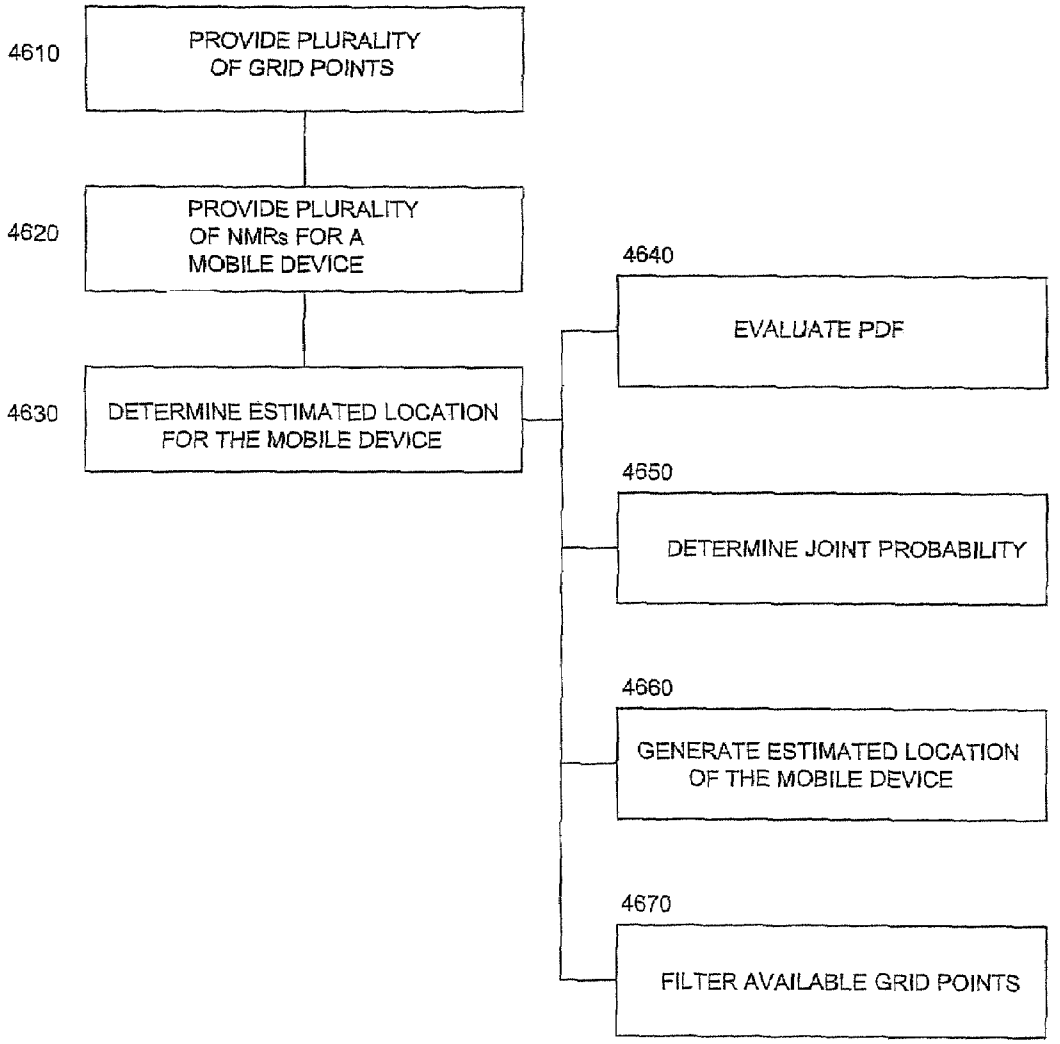

4610
PROVIDE PLURALITY OF GRID POINTS
4620
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4630
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4640
EVALUATE PDF
4650
DETERMINE JOINT PROBABILITY
4660
GENERATE ESTIMATED LOCATION OF THE MOBILE DEVICE
4670
FILTER AVAILABLE GRID POINTS

FIG. 46

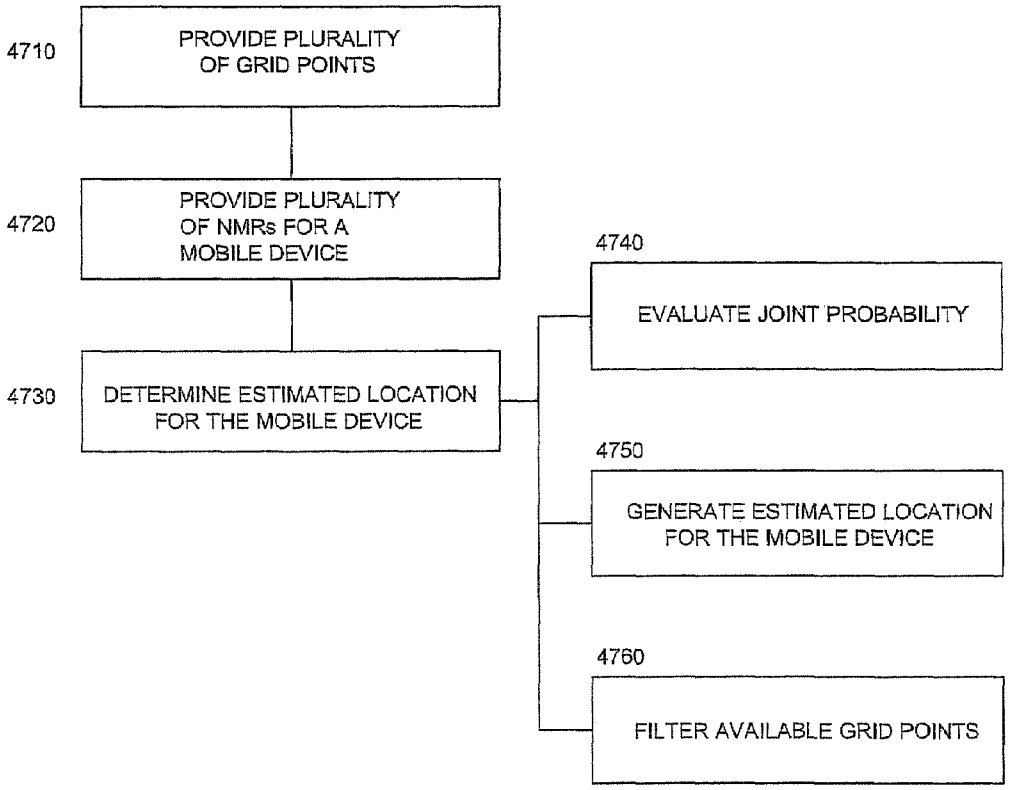

4710
PROVIDE PLURALITY OF GRID POINTS
4720
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4730
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4740
EVALUATE JOINT PROBABILITY
4750
GENERATE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4760
FILTER AVAILABLE GRID POINTS

FIG. 47

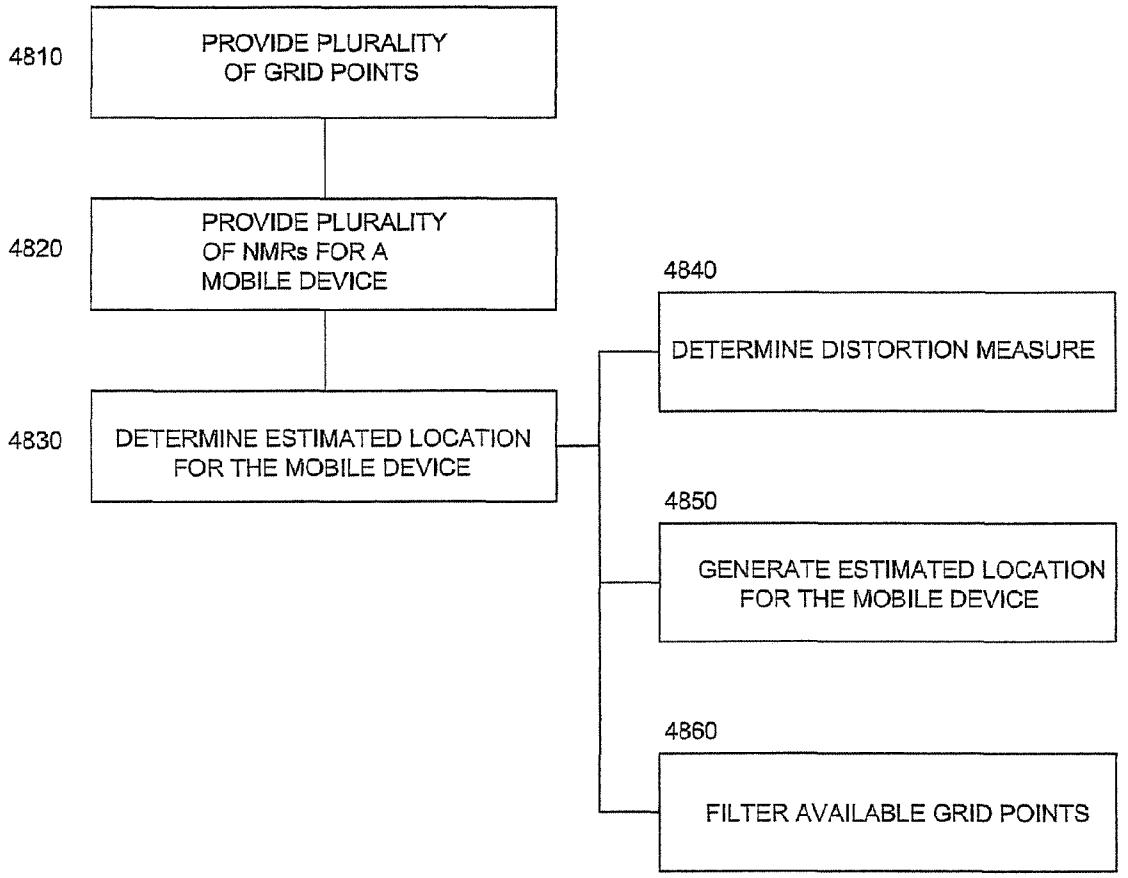

4810
PROVIDE PLURALITY OF GRID POINTS
4820
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4830
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4840
DETERMINE DISTORTION MEASURE
4850
GENERATE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4860
FILTER AVAILABLE GRID POINTS

FIG. 48

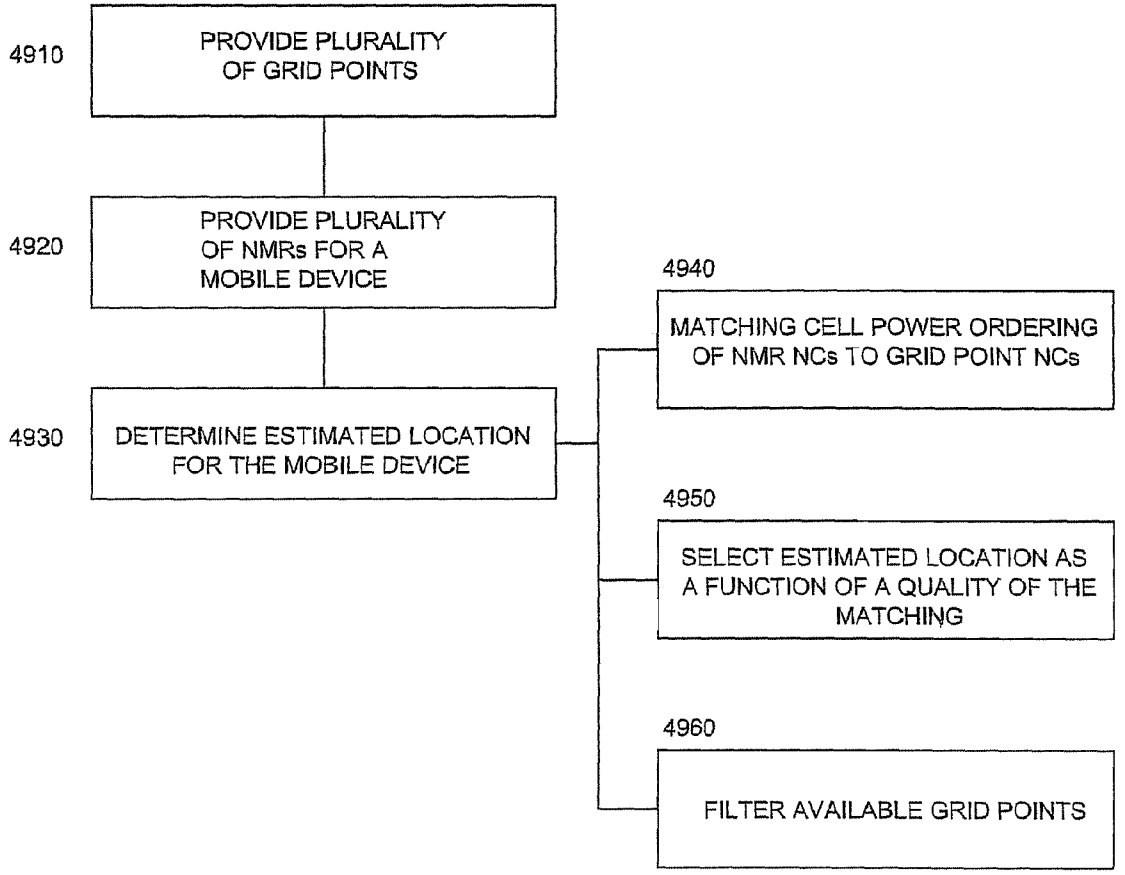

4910
PROVIDE PLURALITY OF GRID POINTS
4920
PROVIDE PLURALITY OF NMRs FOR A MOBILE DEVICE
4930
DETERMINE ESTIMATED LOCATION FOR THE MOBILE DEVICE
4940
MATCHING CELL POWER ORDERING OF NMR NCs TO GRID POINT NCs
4950
SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCHING
4960
FILTER AVAILABLE GRID POINTS

FIG. 49

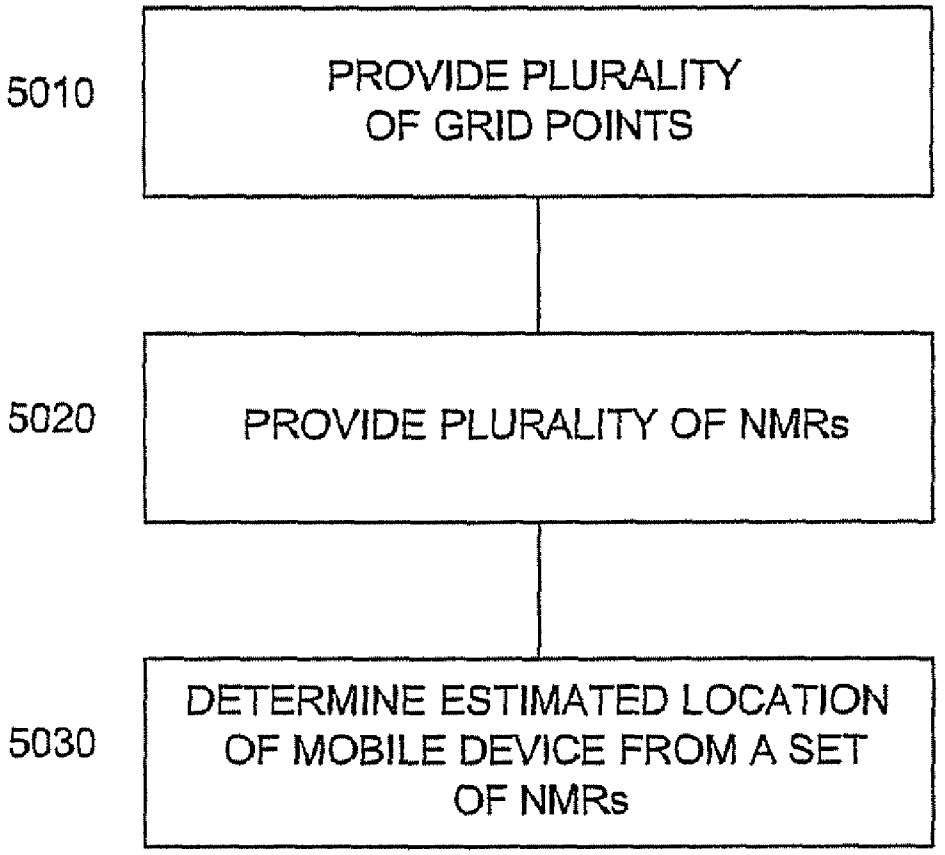

5010
PROVIDE PLURALITY OF GRID POINTS
5020
PROVIDE PLURALITY OF NMRs
5030
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs

FIG. 50

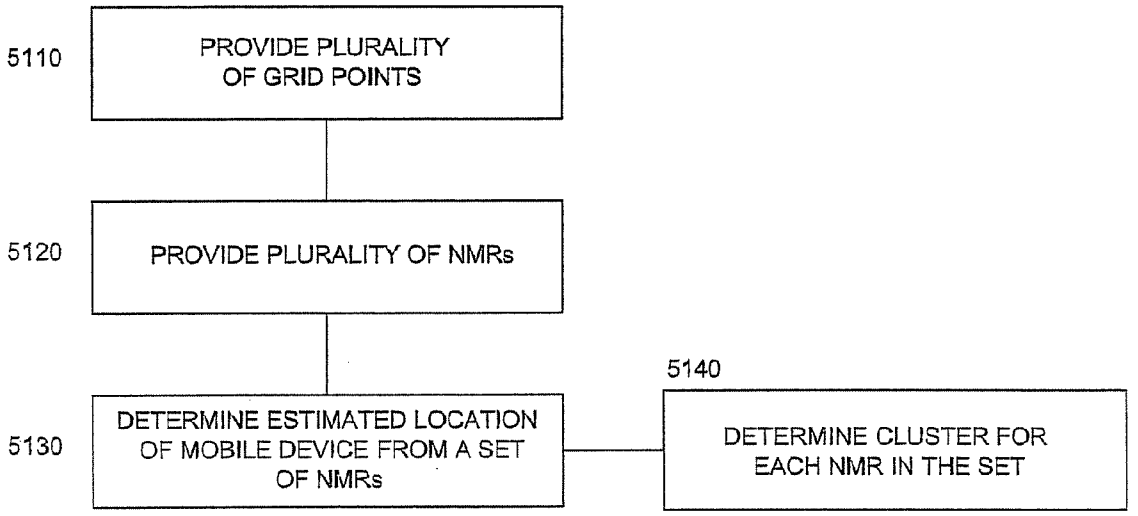

5110
PROVIDE PLURALITY OF GRID POINTS
5120
PROVIDE PLURALITY OF NMRs
5130
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5140
DETERMINE CLUSTER FOR EACH NMR IN THE SET

FIG. 51

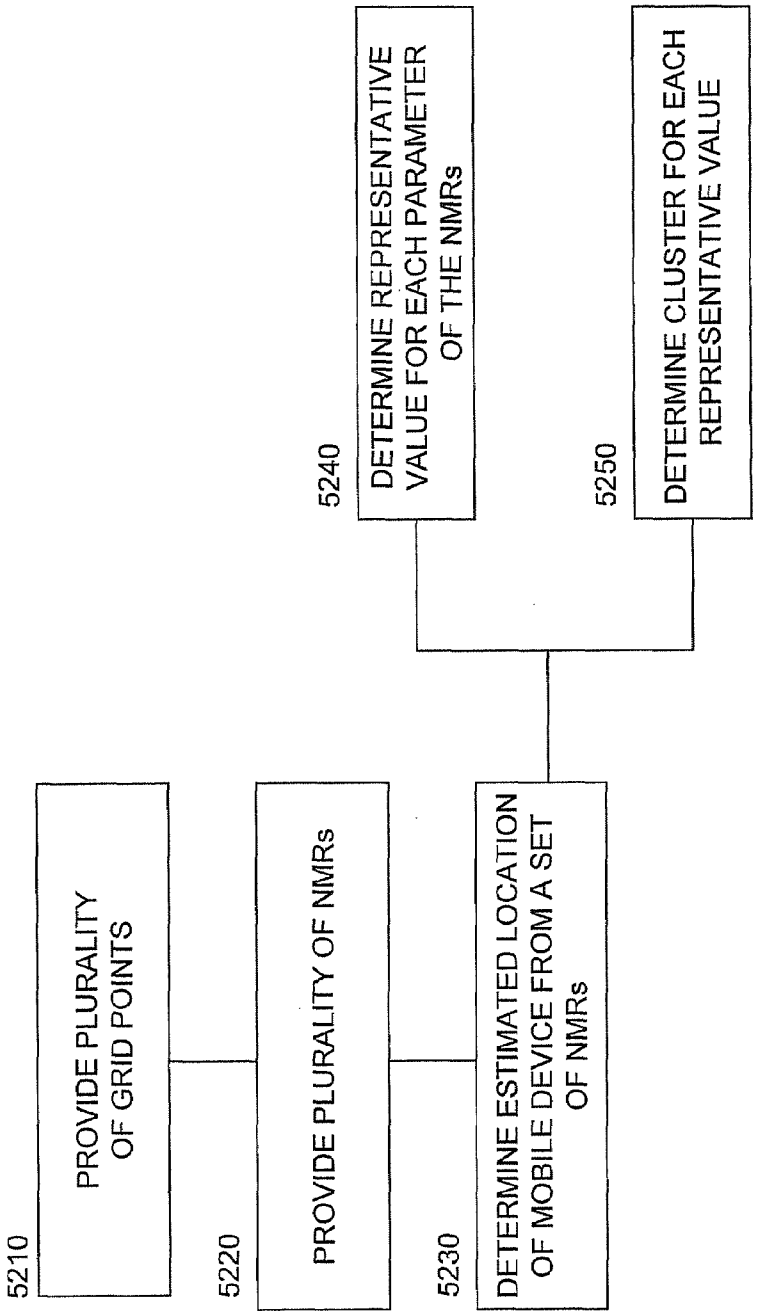

5210
PROVIDE PLURALITY OF GRID POINTS
5220
PROVIDE PLURALITY OF NMRs
5230
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5240
DETERMINE REPRESENTATIVE VALUE FOR EACH PARAMETER OF THE NMRs
5250
DETERMINE CLUSTER FOR EACH REPRESENTATIVE VALUE

FIGURE 52

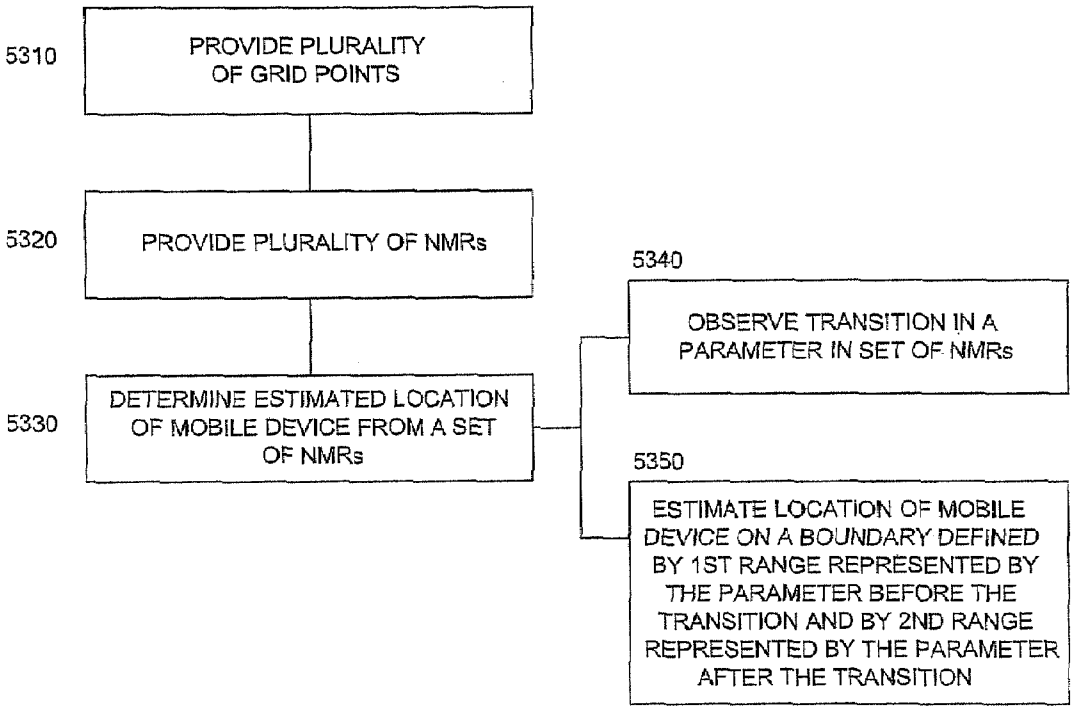

5310
PROVIDE PLURALITY OF GRID POINTS
5320
PROVIDE PLURALITY OF NMRs
5330
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5340
OBSERVE TRANSITION IN A PARAMETER IN SET OF NMRs
5350
ESTIMATE LOCATION OF MOBILE DEVICE ON A BOUNDARY DEFINED BY 1ST RANGE REPRESENTED BY THE PARAMETER BEFORE THE TRANSITION AND BY 2ND RANGE REPRESENTED BY THE PARAMETER AFTER THE TRANSITION

FIG. 53

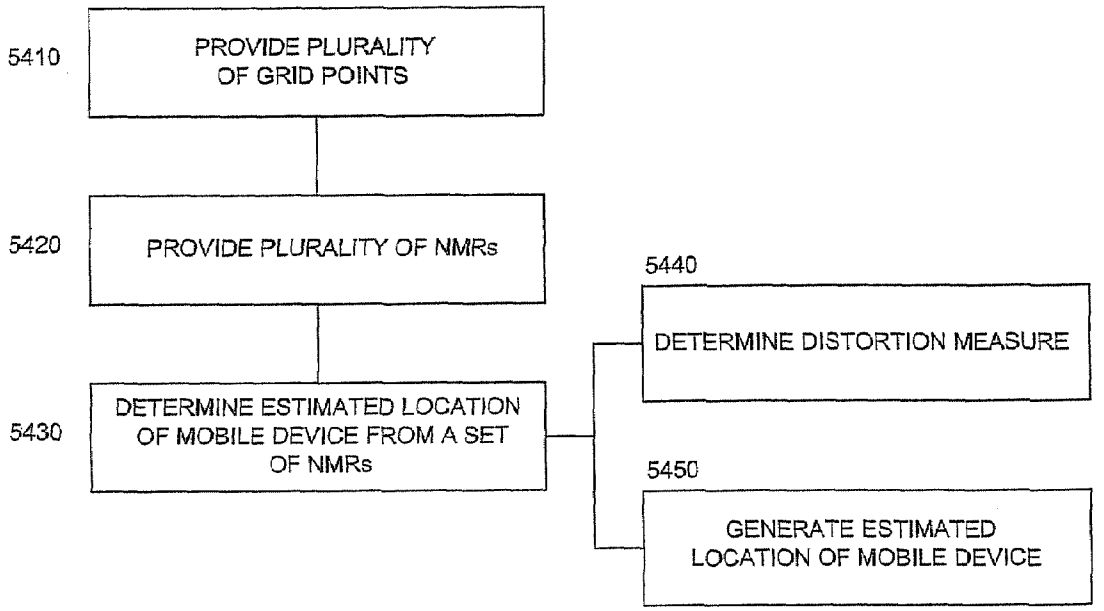

5410
PROVIDE PLURALITY OF GRID POINTS
5420
PROVIDE PLURALITY OF NMRs
5430
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5440
DETERMINE DISTORTION MEASURE
5450
GENERATE ESTIMATED LOCATION OF MOBILE DEVICE

FIG. 54

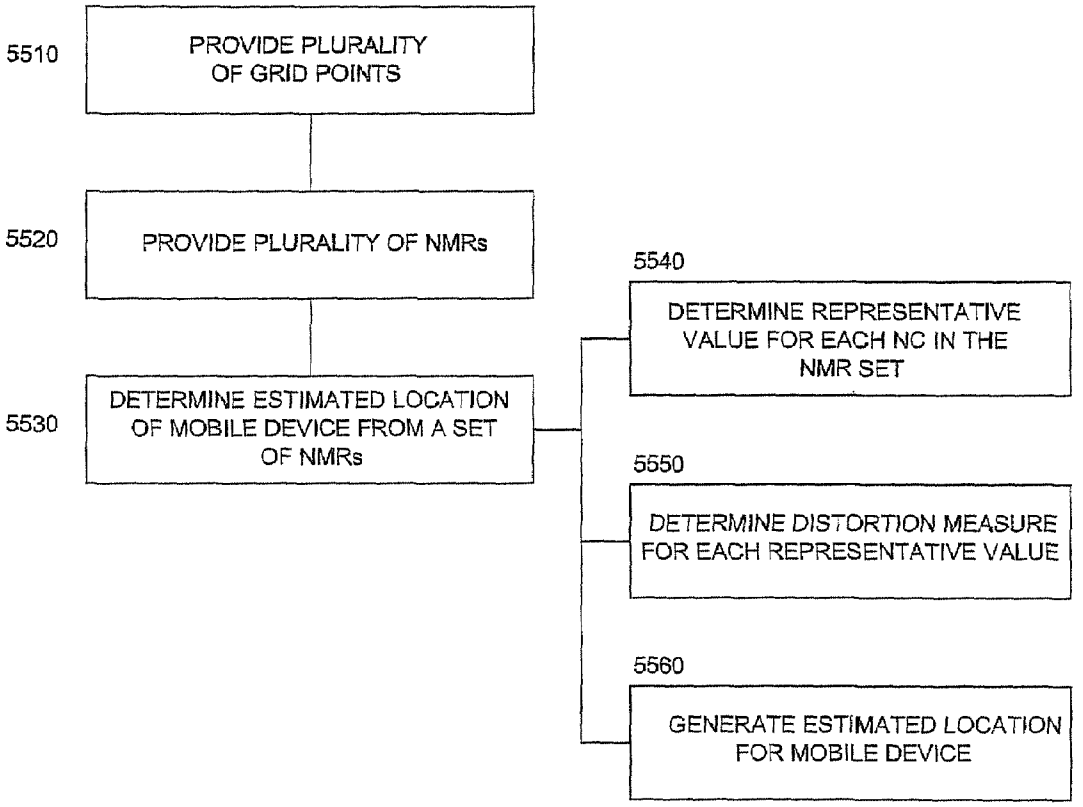

5510
PROVIDE PLURALITY OF GRID POINTS
5520
PROVIDE PLURALITY OF NMRs
5530
DETERMINE ESTIMATED LOCATION OF MOBILE DEVICE FROM A SET OF NMRs
5540
DETERMINE REPRESENTATIVE VALUE FOR EACH NC IN THE NMR SET
5550
DETERMINE DISTORTION MEASURE FOR EACH REPRESENTATIVE VALUE
5560
GENERATE ESTIMATED LOCATION FOR MOBILE DEVICE

FIG. 55

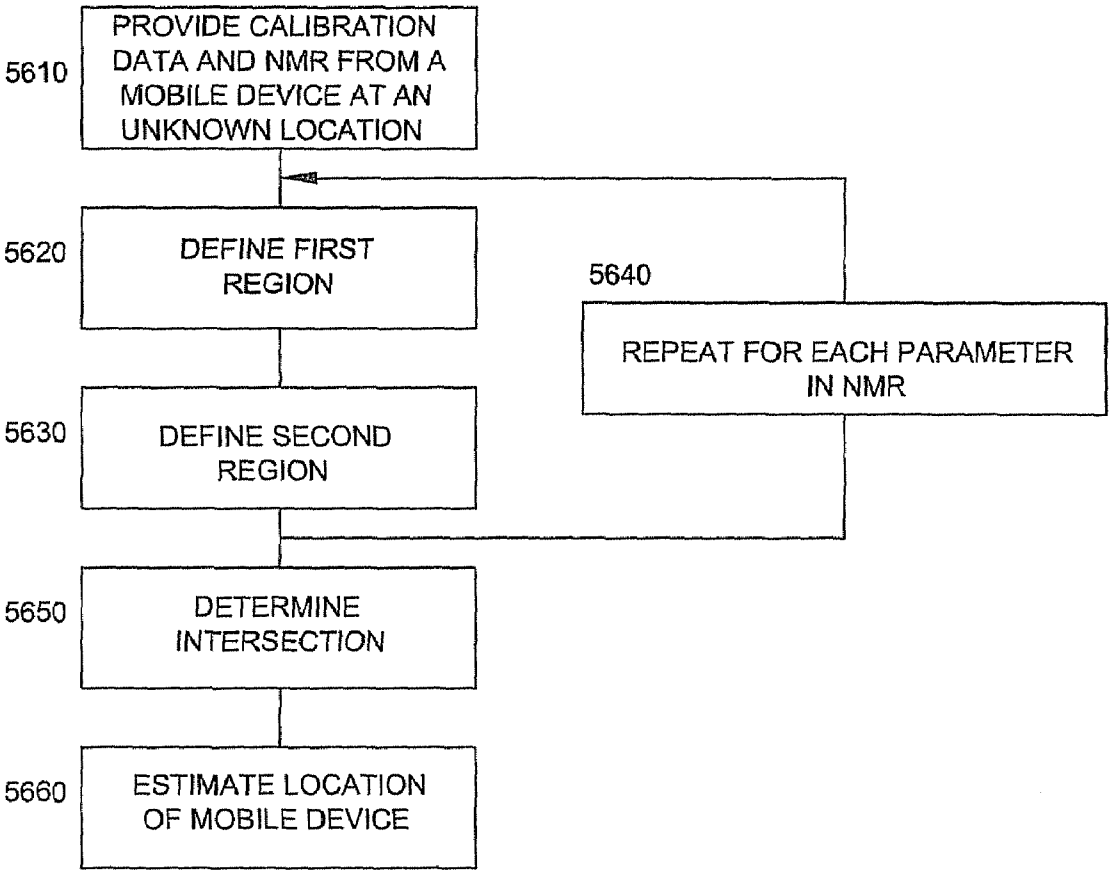

5610
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5620
DEFINE FIRST REGION
5640
REPEAT FOR EACH PARAMETER IN NMR
5630
DEFINE SECOND REGION
5650
DETERMINE INTERSECTION
5660
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 56

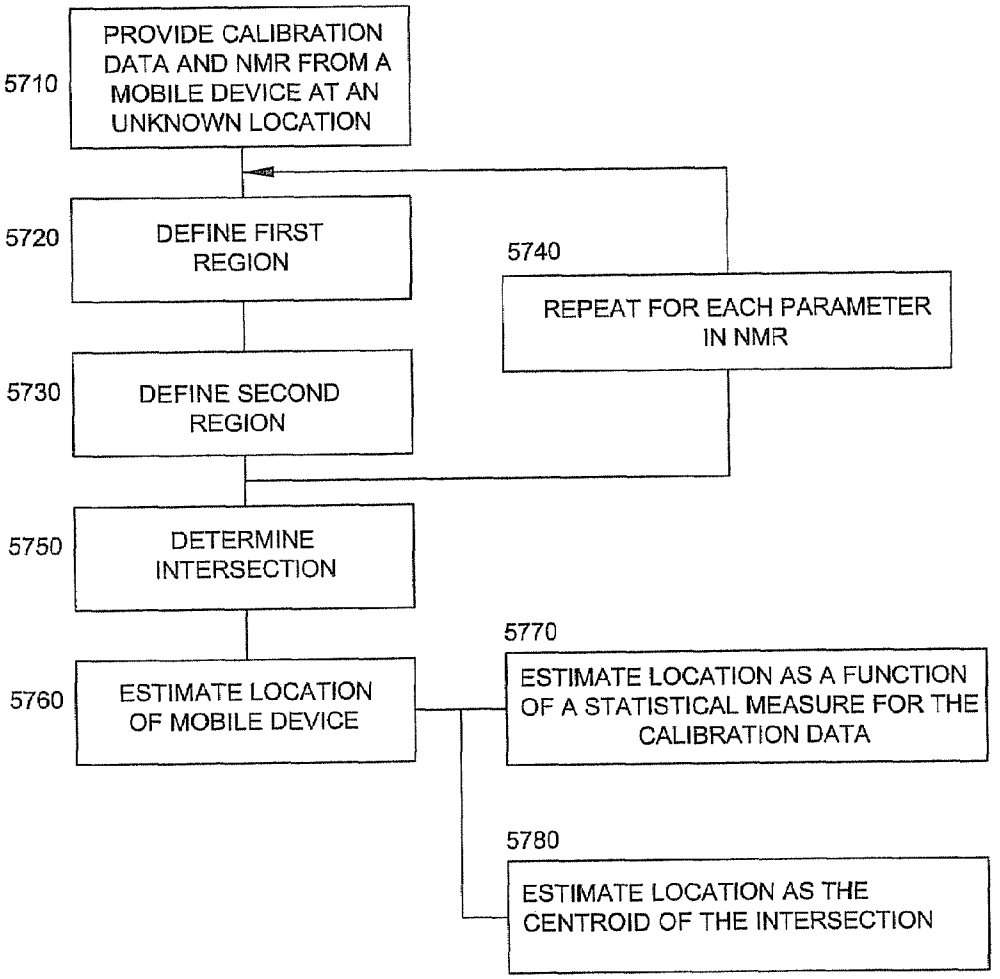

5710
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5720
DEFINE FIRST REGION
5740
REPEAT FOR EACH PARAMETER IN NMR
5730
DEFINE SECOND REGION
5750
DETERMINE INTERSECTION
5770
5760
ESTIMATE LOCATION OF MOBILE DEVICE
ESTIMATE LOCATION AS A FUNCTION OF A STATISTICAL MEASURE FOR THE CALIBRATION DATA
5780
ESTIMATE LOCATION AS THE CENTROID OF THE INTERSECTION

FIG. 57

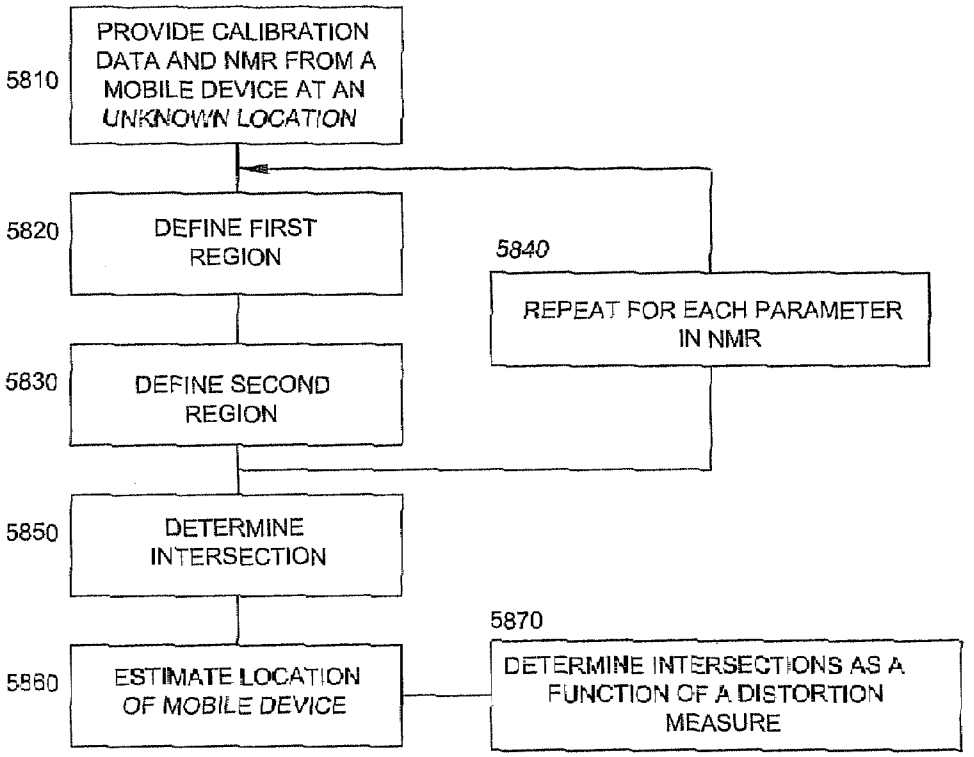

5810
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5820
DEFINE FIRST REGION
5840
REPEAT FOR EACH PARAMETER IN NMR
5830
DEFINE SECOND REGION
5850
DETERMINE INTERSECTION
5870
5860
ESTIMATE LOCATION OF MOBILE DEVICE
DETERMINE INTERSECTIONS AS A FUNCTION OF A DISTORTION MEASURE

FIG. 58

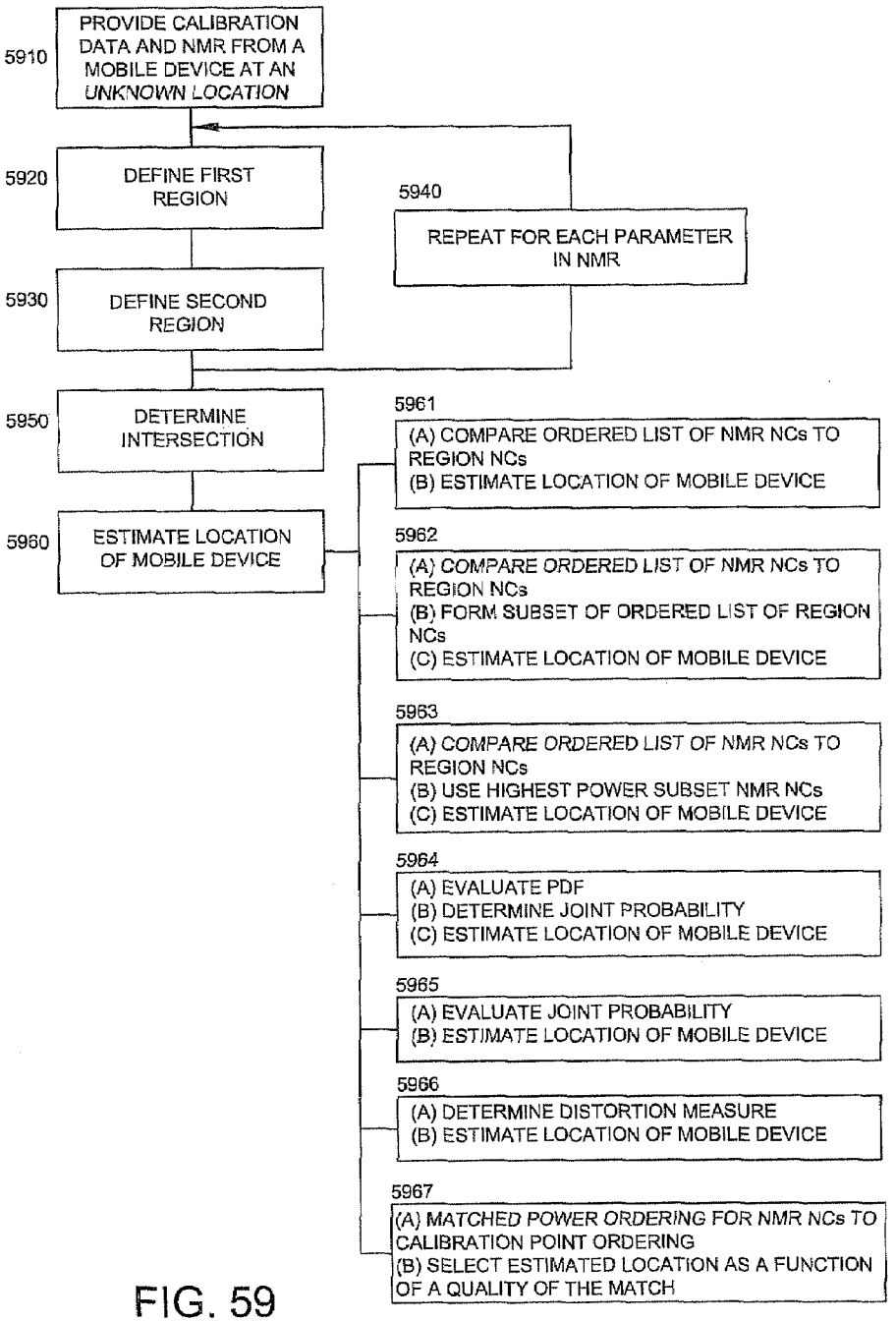

5910
PROVIDE CALIBRATION DATA AND NMR FROM A MOBILE DEVICE AT AN UNKNOWN LOCATION
5920
DEFINE FIRST REGION
5940
REPEAT FOR EACH PARAMETER IN NMR
5930
DEFINE SECOND REGION
5950
DETERMINE INTERSECTION
5960
ESTIMATE LOCATION OF MOBILE DEVICE
5961
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5962
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5963
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5964
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
5965
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5966
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
5967
(A) MATCHED POWER ORDERING FOR NMR NCs TO CALIBRATION POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH

FIG. 59

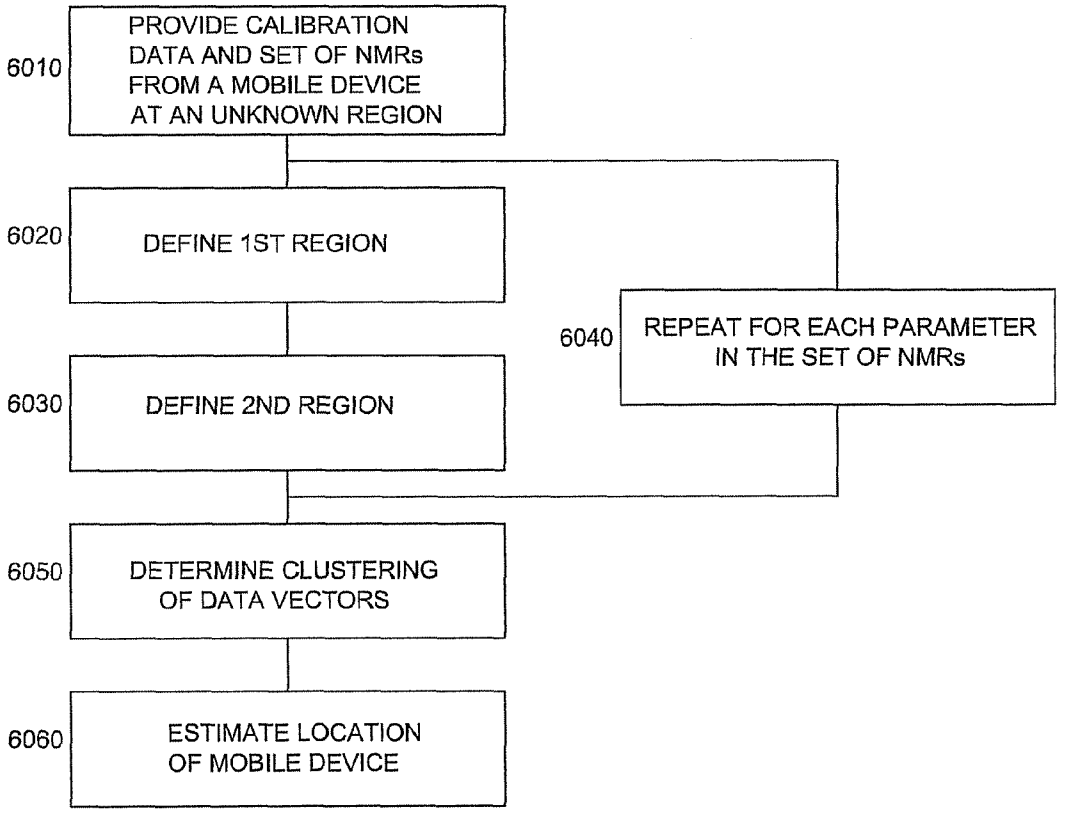

6010
PROVIDE CALIBRATION DATA AND SET OF NMRs FROM A MOBILE DEVICE AT AN UNKNOWN REGION
6020
DEFINE 1ST REGION
6030
DEFINE 2ND REGION
6040
REPEAT FOR EACH PARAMETER IN THE SET OF NMRs
6050
DETERMINE CLUSTERING OF DATA VECTORS
6060
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 60

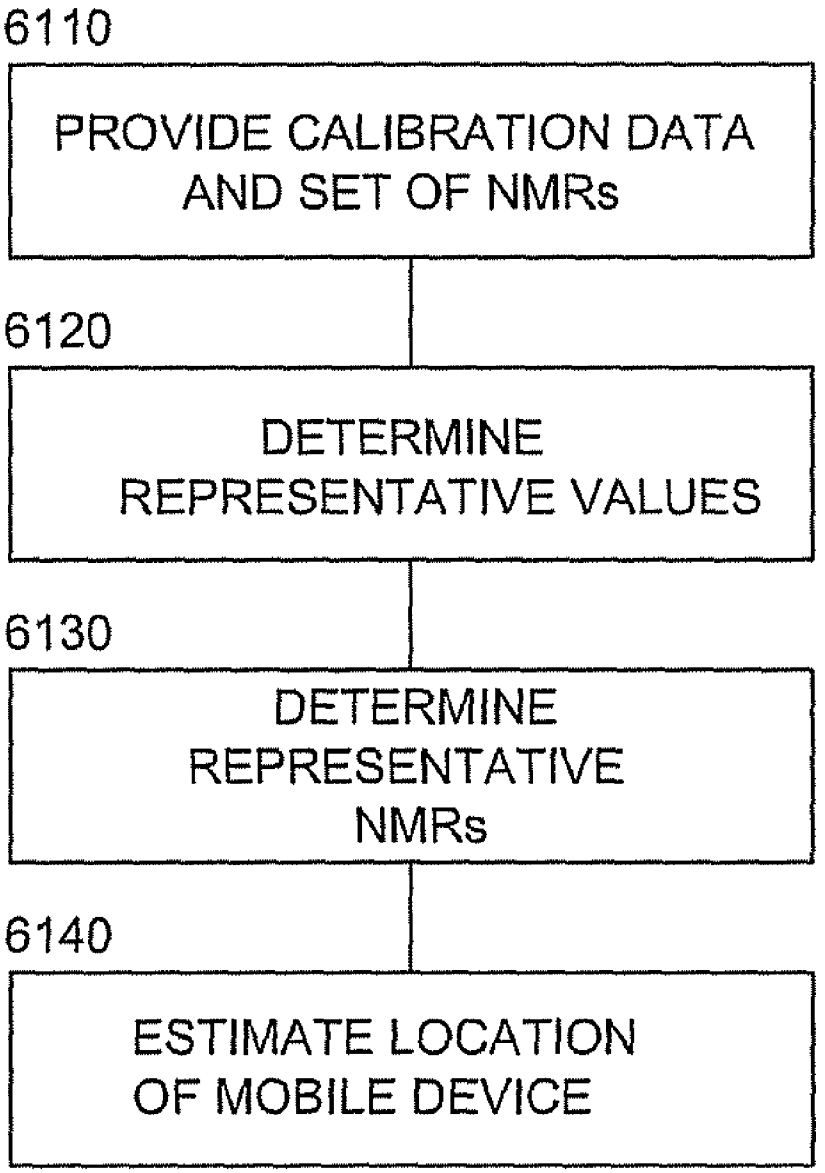

6110
PROVIDE CALIBRATION DATA AND SET OF NMRs
6120
DETERMINE REPRESENTATIVE VALUES
6130
DETERMINE REPRESENTATIVE NMRs
6140
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 61

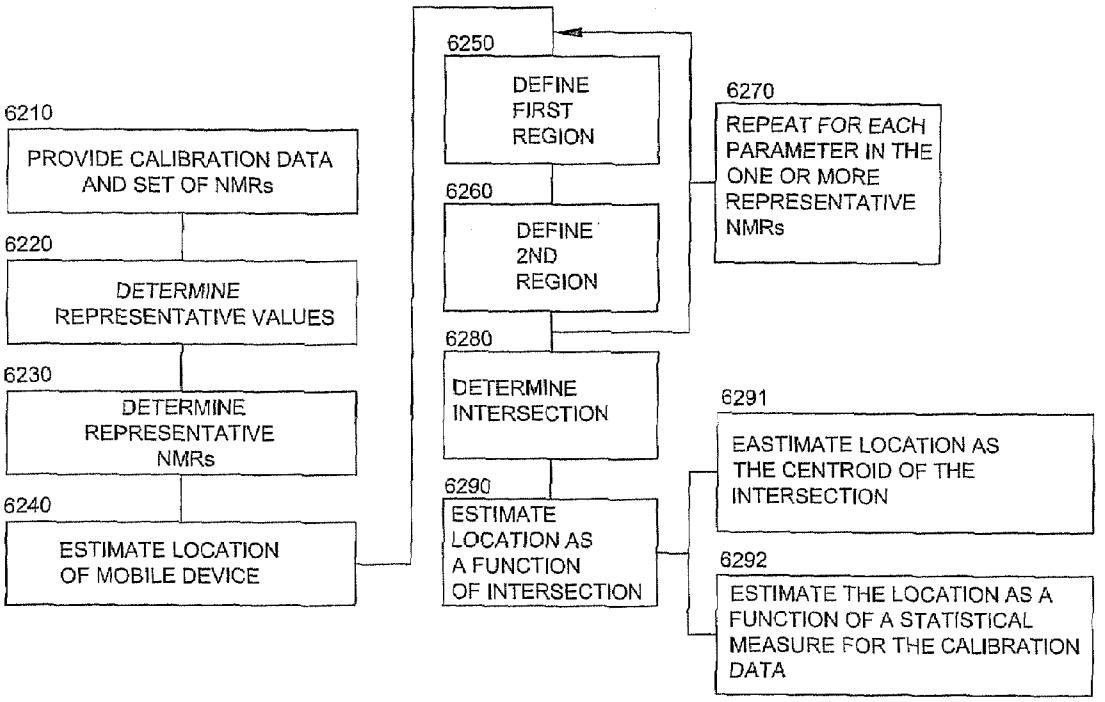

6210
PROVIDE CALIBRATION DATA AND SET OF NMRs
6220
DETERMINE REPRESENTATIVE VALUES
6230
DETERMINE REPRESENTATIVE NMRs
6240
ESTIMATE LOCATION OF MOBILE DEVICE
6250
DEFINE FIRST REGION
6260
DEFINE 2ND REGION
6270
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6280
DETERMINE INTERSECTION
6290
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION
6291
EASTIMATE LOCATION AS THE CENTROID OF THE INTERSECTION
6292
ESTIMATE THE LOCATION AS A FUNCTION OF A STATISTICAL MEASURE FOR THE CALIBRATION DATA

FIG. 62

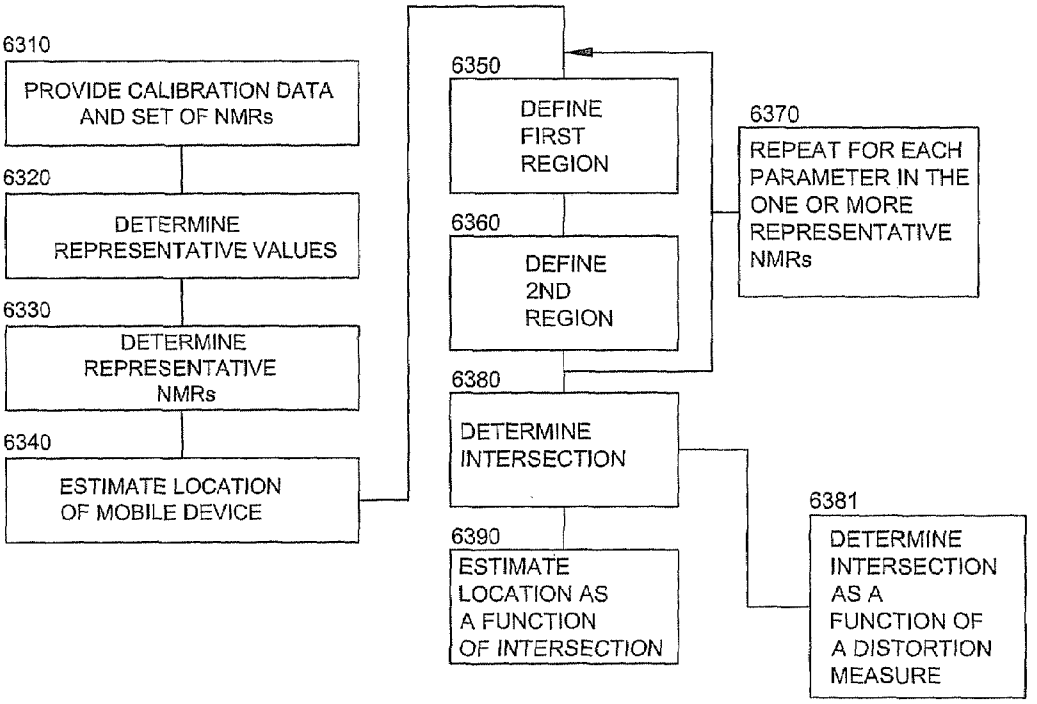

6310
PROVIDE CALIBRATION DATA AND SET OF NMRs
6320
DETERMINE REPRESENTATIVE VALUES
6330
DETERMINE REPRESENTATIVE NMRs
6340
ESTIMATE LOCATION OF MOBILE DEVICE
6350
DEFINE FIRST REGION
6360
DEFINE 2ND REGION
6370
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6380
DETERMINE INTERSECTION
6381
DETERMINE INTERSECTION AS A FUNCTION OF A DISTORTION MEASURE
6390
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION

FIG. 63

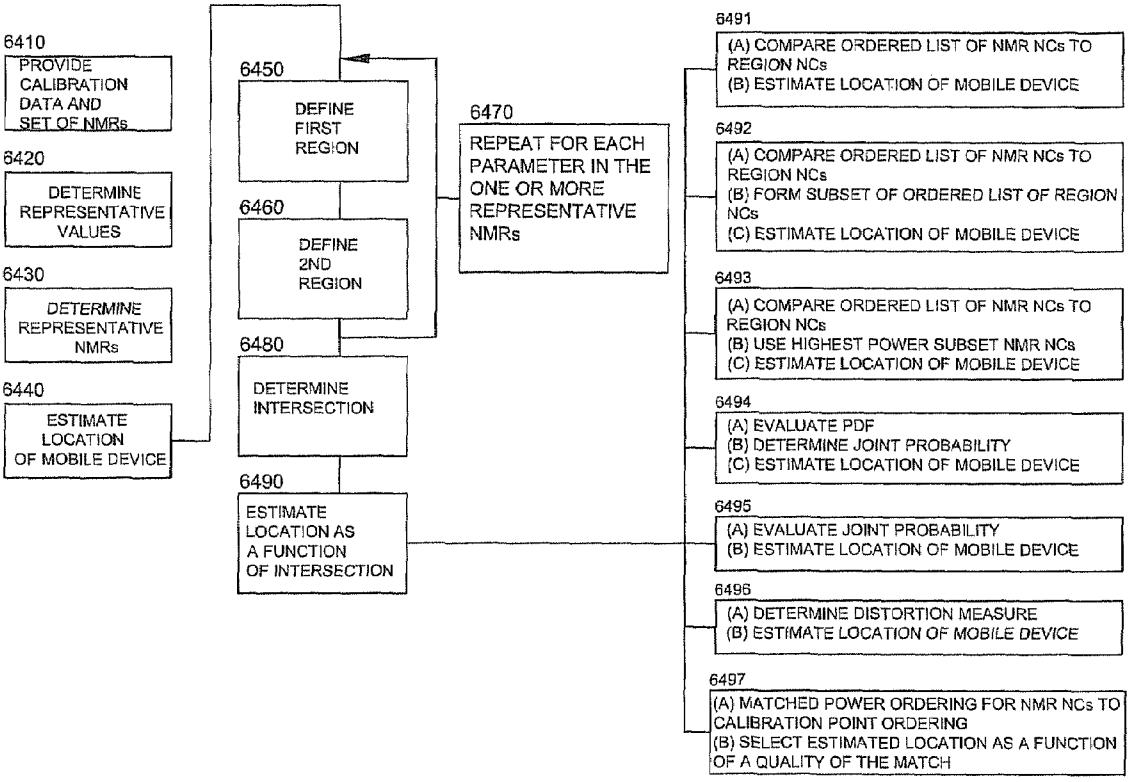

6410
PROVIDE CALIBRATION DATA AND SET OF NMRs
6420
DETERMINE REPRESENTATIVE VALUES
6430
DETERMINE REPRESENTATIVE NMRs
6440
ESTIMATE LOCATION OF MOBILE DEVICE
6450
DEFINE FIRST REGION
6460
DEFINE 2ND REGION
6470
REPEAT FOR EACH PARAMETER IN THE ONE OR MORE REPRESENTATIVE NMRs
6480
DETERMINE INTERSECTION
6490
ESTIMATE LOCATION AS A FUNCTION OF INTERSECTION
6491
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6492
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6493
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6494
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6495
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6496
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6497
(A) MATCHED POWER ORDERING FOR NMR NCs TO CALIBRATION POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH

FIG. 64

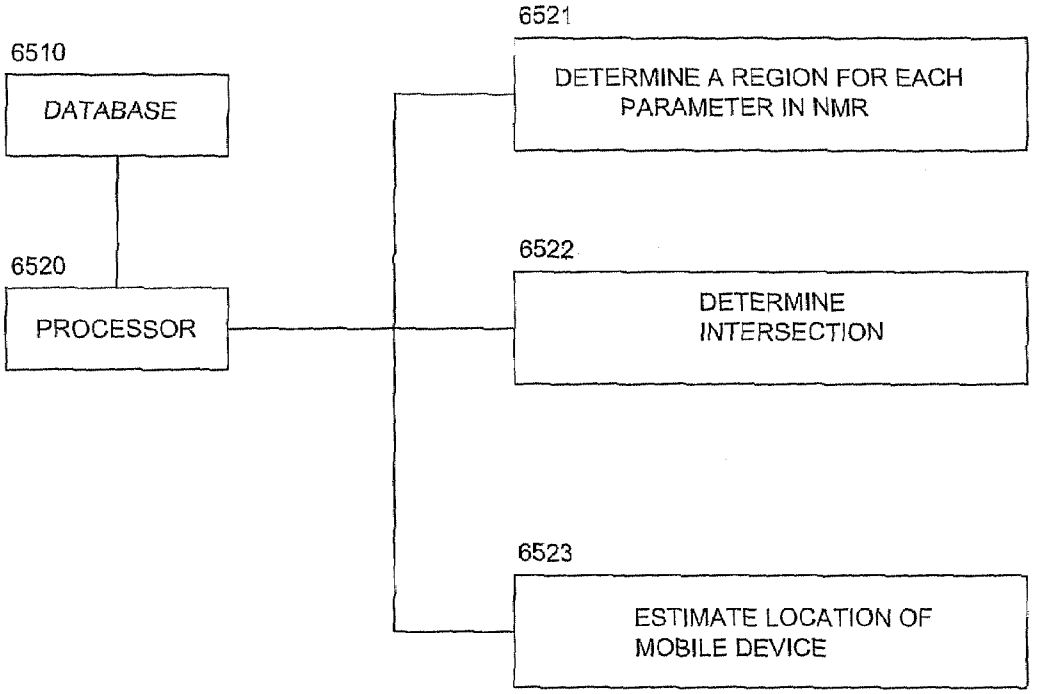

6510
DATABASE
6520
PROCESSOR
6521
DETERMINE A REGION FOR EACH PARAMETER IN NMR
6522
DETERMINE INTERSECTION
6523
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 65

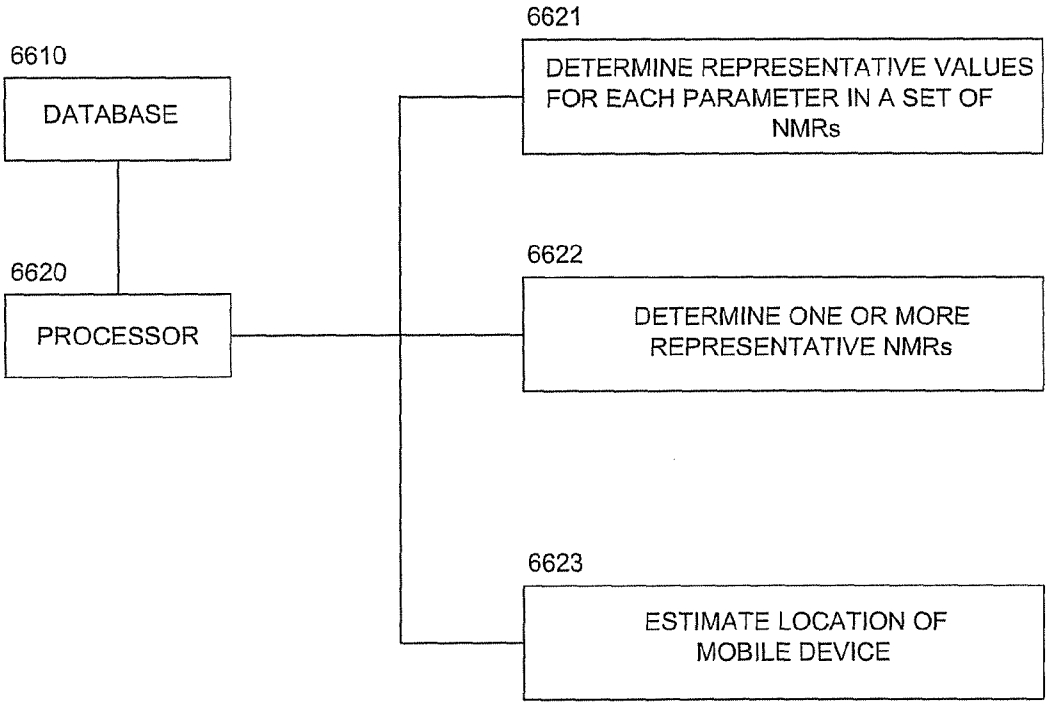

6610
DATABASE
6620
PROCESSOR
6621
DETERMINE REPRESENTATIVE VALUES FOR EACH PARAMETER IN A SET OF NMRs
6622
DETERMINE ONE OR MORE REPRESENTATIVE NMRs
6623
ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 66

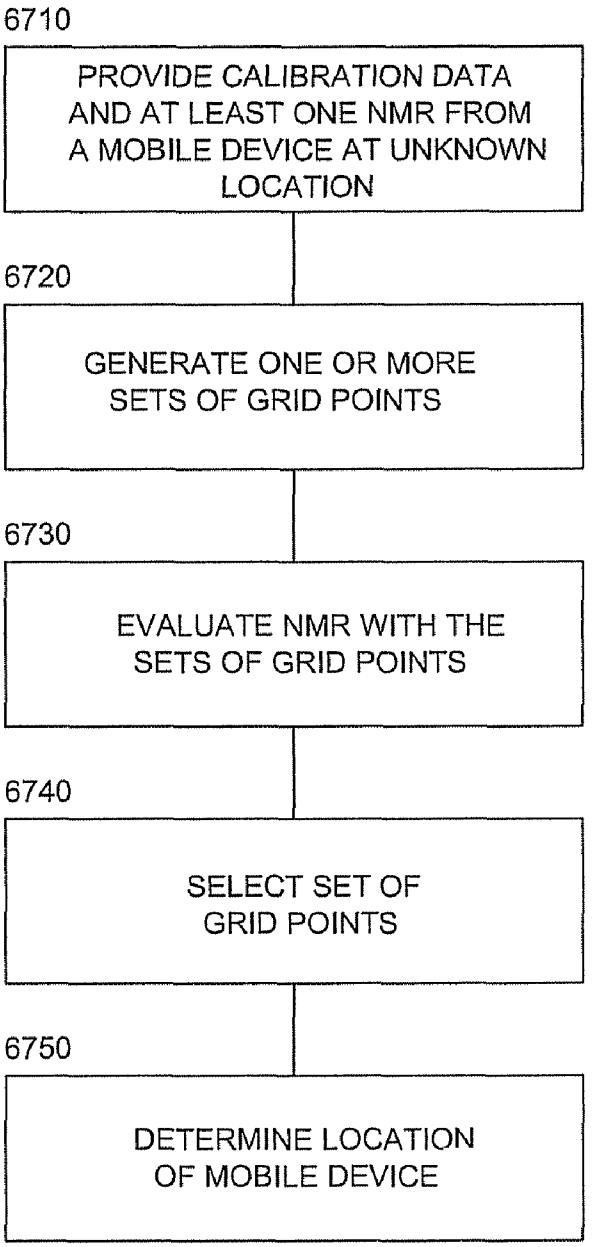

6710
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6720
GENERATE ONE OR MORE SETS OF GRID POINTS
6730
EVALUATE NMR WITH THE SETS OF GRID POINTS
6740
SELECT SET OF GRID POINTS
6750
DETERMINE LOCATION OF MOBILE DEVICE

FIG. 67

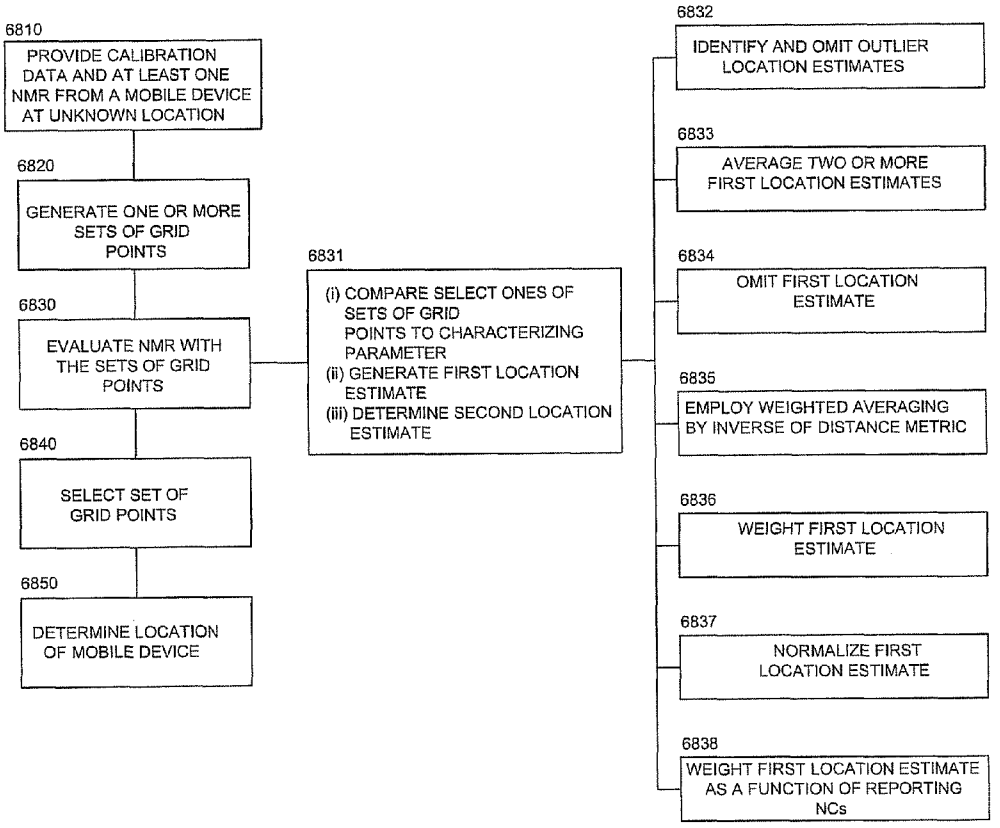

6810
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6820
GENERATE ONE OR MORE SETS OF GRID POINTS
6830
EVALUATE NMR WITH THE SETS OF GRID POINTS
6840
SELECT SET OF GRID POINTS
6850
DETERMINE LOCATION OF MOBILE DEVICE
6831
(i) COMPARE SELECT ONES OF SETS OF GRID POINTS TO CHARACTERIZING PARAMETER
(ii) GENERATE FIRST LOCATION ESTIMATE
(iii) DETERMINE SECOND LOCATION ESTIMATE
6832
IDENTIFY AND OMIT OUTLIER LOCATION ESTIMATES
6833
AVERAGE TWO OR MORE FIRST LOCATION ESTIMATES
6834
OMIT FIRST LOCATION ESTIMATE
6835
EMPLOY WEIGHTED AVERAGING BY INVERSE OF DISTANCE METRIC
6836
WEIGHT FIRST LOCATION ESTIMATE
6837
NORMALIZE FIRST LOCATION ESTIMATE
6838
WEIGHT FIRST LOCATION ESTIMATE AS A FUNCTION OF REPORTING NCs

FIG. 68

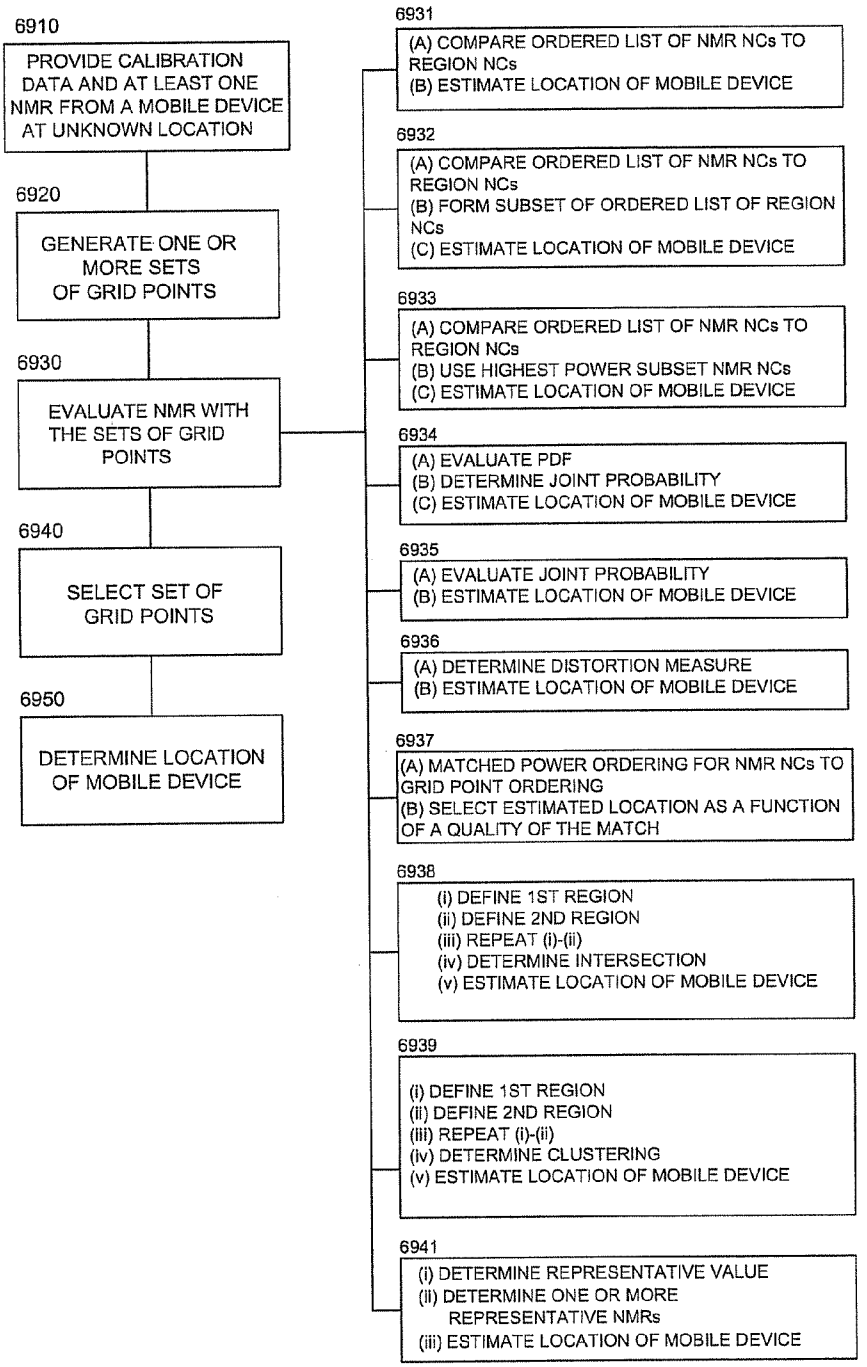

6910
PROVIDE CALIBRATION DATA AND AT LEAST ONE NMR FROM A MOBILE DEVICE AT UNKNOWN LOCATION
6920
GENERATE ONE OR MORE SETS OF GRID POINTS
6930
EVALUATE NMR WITH THE SETS OF GRID POINTS
6940
SELECT SET OF GRID POINTS
6950
DETERMINE LOCATION OF MOBILE DEVICE
6931
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6932
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6933
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6934
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
6935
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6936
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
6937
(A) MATCHED POWER ORDERING FOR NMR NCs TO GRID POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH
6938
(i) DEFINE 1ST REGION
(ii) DEFINE 2ND REGION
(iii) REPEAT (i)-(ii)
(iv) DETERMINE INTERSECTION
(v) ESTIMATE LOCATION OF MOBILE DEVICE
6939
(i) DEFINE 1ST REGION
(ii) DEFINE 2ND REGION
(iii) REPEAT (i)-(ii)
(iv) DETERMINE CLUSTERING
(v) ESTIMATE LOCATION OF MOBILE DEVICE
6941
(i) DETERMINE REPRESENTATIVE VALUE
(ii) DETERMINE ONE OR MORE REPRESENTATIVE NMRs
(iii) ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 69

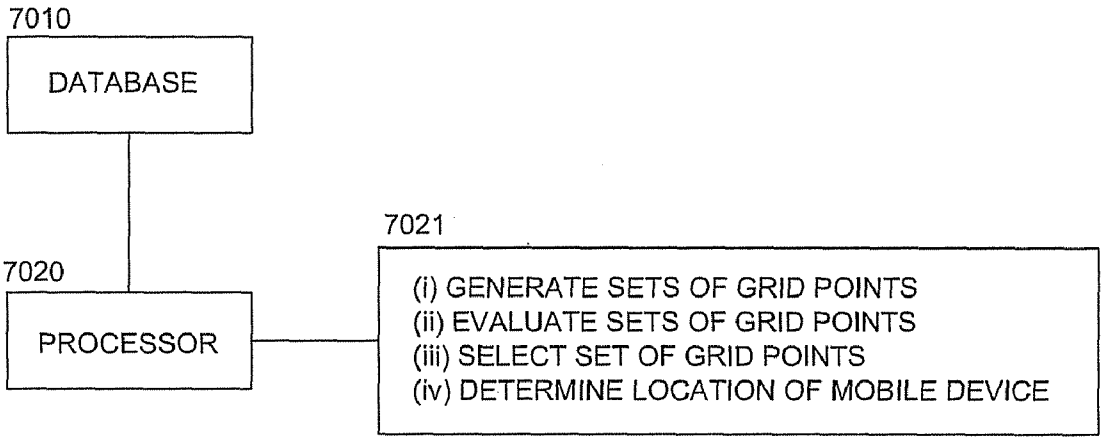

7010
DATABASE
7020
PROCESSOR
7021
(i) GENERATE SETS OF GRID POINTS
(ii) EVALUATE SETS OF GRID POINTS
(iii) SELECT SET OF GRID POINTS
(iv) DETERMINE LOCATION OF MOBILE DEVICE

FIG. 70

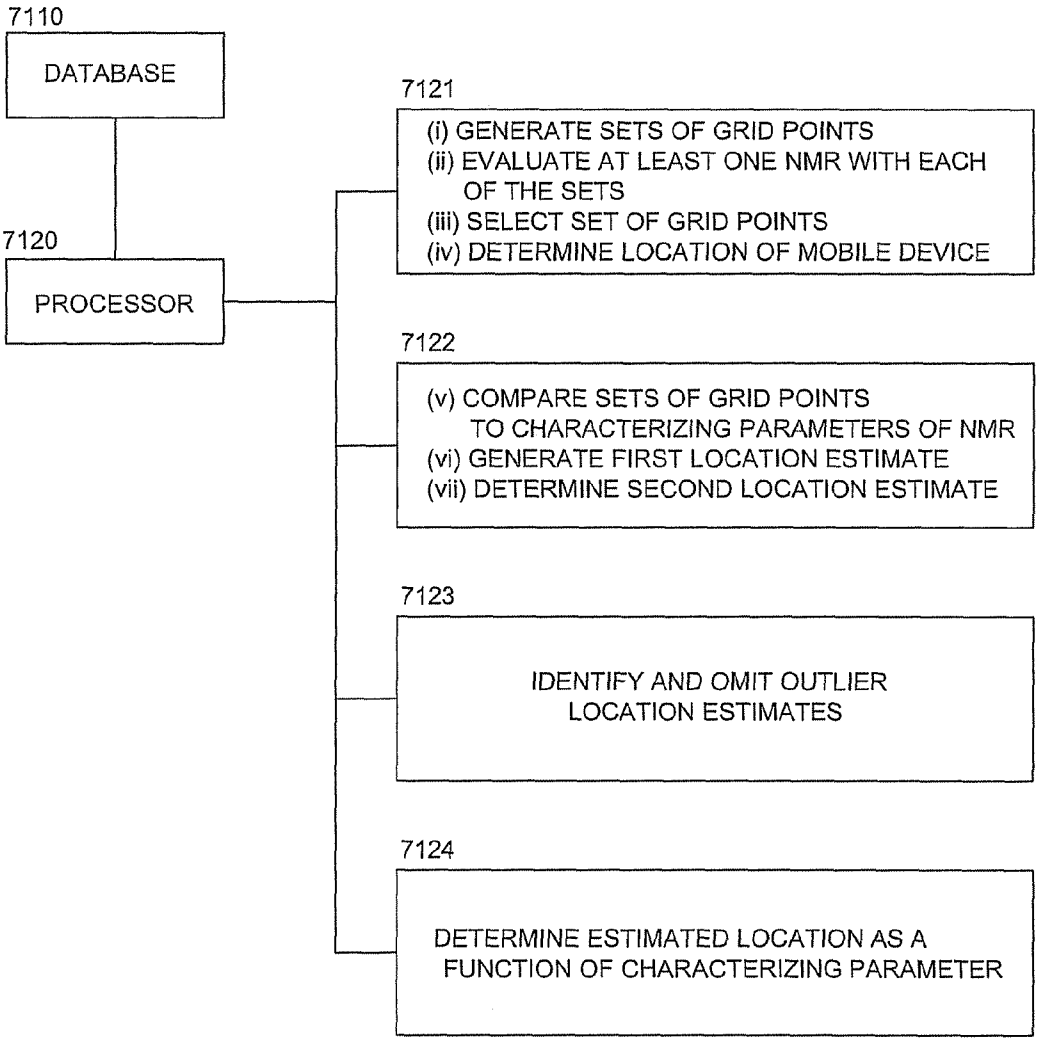

7110
DATABASE
7120
PROCESSOR
7121
(i) GENERATE SETS OF GRID POINTS
(ii) EVALUATE AT LEAST ONE NMR WITH EACH OF THE SETS
(iii) SELECT SET OF GRID POINTS
(iv) DETERMINE LOCATION OF MOBILE DEVICE
7122
(v) COMPARE SETS OF GRID POINTS TO CHARACTERIZING PARAMETERS OF NMR
(vi) GENERATE FIRST LOCATION ESTIMATE
(vii) DETERMINE SECOND LOCATION ESTIMATE
7123
IDENTIFY AND OMIT OUTLIER LOCATION ESTIMATES
7124
DETERMINE ESTIMATED LOCATION AS A FUNCTION OF CHARACTERIZING PARAMETER

FIG. 71

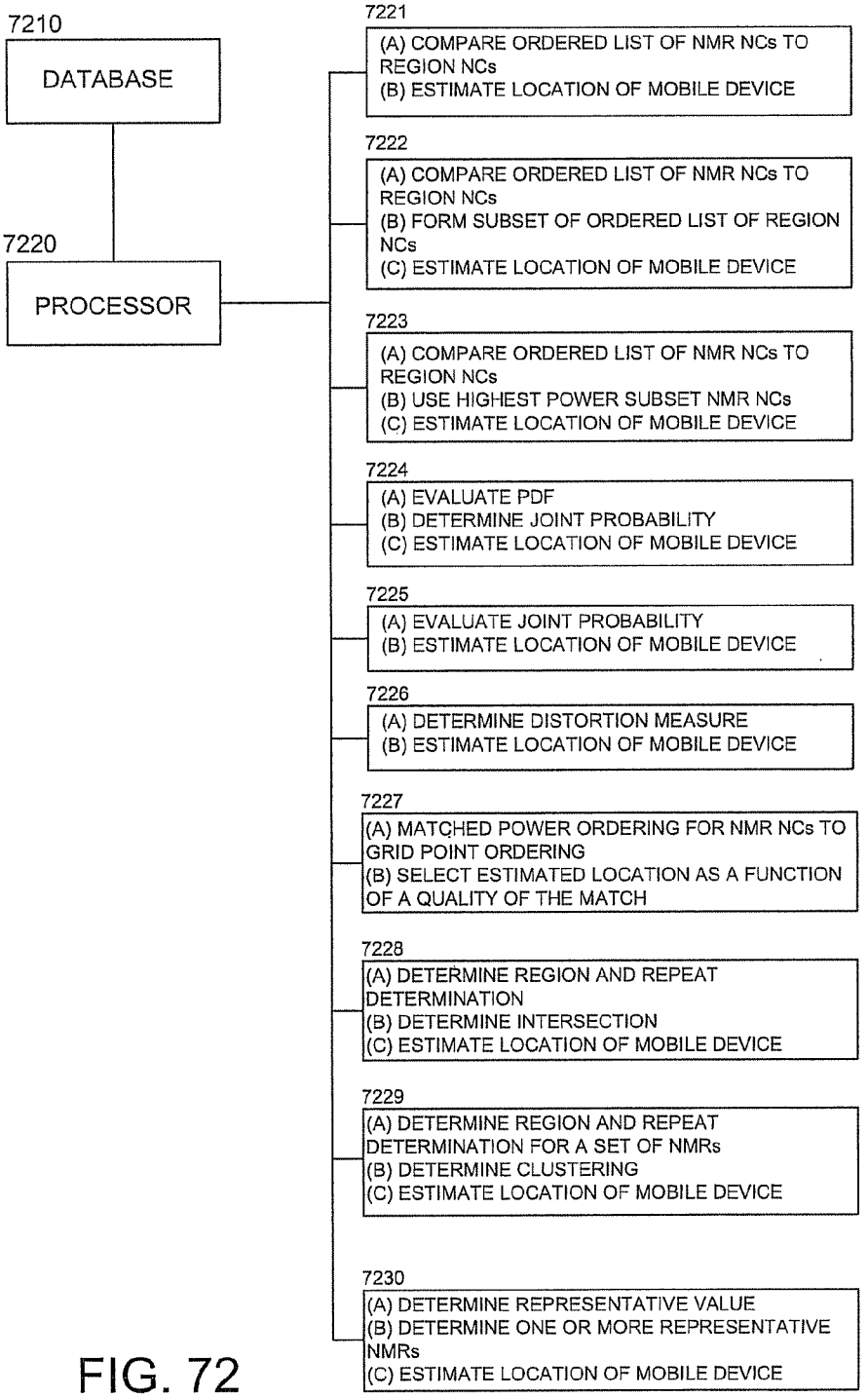

7210
DATABASE
7220
PROCESSOR
7221
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7222
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) FORM SUBSET OF ORDERED LIST OF REGION NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7223
(A) COMPARE ORDERED LIST OF NMR NCs TO REGION NCs
(B) USE HIGHEST POWER SUBSET NMR NCs
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7224
(A) EVALUATE PDF
(B) DETERMINE JOINT PROBABILITY
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7225
(A) EVALUATE JOINT PROBABILITY
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7226
(A) DETERMINE DISTORTION MEASURE
(B) ESTIMATE LOCATION OF MOBILE DEVICE
7227
(A) MATCHED POWER ORDERING FOR NMR NCs TO GRID POINT ORDERING
(B) SELECT ESTIMATED LOCATION AS A FUNCTION OF A QUALITY OF THE MATCH
7228
(A) DETERMINE REGION AND REPEAT DETERMINATION
(B) DETERMINE INTERSECTION
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7229
(A) DETERMINE REGION AND REPEAT DETERMINATION FOR A SET OF NMRs
(B) DETERMINE CLUSTERING
(C) ESTIMATE LOCATION OF MOBILE DEVICE
7230
(A) DETERMINE REPRESENTATIVE VALUE
(B) DETERMINE ONE OR MORE REPRESENTATIVE NMRs
(C) ESTIMATE LOCATION OF MOBILE DEVICE

FIG. 72

# SYSTEM AND METHOD FOR GENERATING A LOCATION ESTIMATE USING UNIFORM AND NON-UNIFORM GRID POINTS

## CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority benefit to and hereby incorporates by reference in its entirety co-pending U.S. Provisional Patent Application Ser. No. 60/899,379 filed on 5 Feb. 2007.

## BACKGROUND

The present subject matter is directed generally towards a system and method for estimating the location of a wireless mobile device that is in communication with a wireless communications network. More specifically, the present subject matter relates to the problem of estimating the location of a wireless mobile device using information from one or more Network Measurement Reports ("NMRs") which may be generated by a wireless communications network or the mobile device.

As is well known in the art, the use of wireless communication devices such as telephones, pagers, personal digital assistants, laptop computers, anti-theft devices, etc., hereinafter referred to collectively as "mobile devices", has become prevalent in today's society. Along with the proliferation of these mobile devices is the safety concern associated with the need to locate the mobile device, for example in an emergency situation. For example, the Federal Communication Commission ("FCC") has issued a geolocation mandate for providers of wireless telephone communication services that puts in place a schedule and an accuracy standard under which the providers of wireless communications must implement geolocation technology for wireless telephones when used to make a 911 emergency telephone call (FCC 94-102 E911). In addition to E911 emergency related issues, there has been increased interest in technology which can determine the geographic position, or "geolocate" a mobile device. For example, wireless telecommunications providers are developing location-enabled services for their subscribers including roadside assistance, turn-by-turn driving directions, concierge services, location-specific billing rates and location-specific advertising.

Currently in the art, there are a number of different ways to geolocate a mobile device. For example, providers of wireless communication services have installed mobile device location capabilities into their networks. In operation, these network overlay location systems take measurements on radio frequency ("RF") transmissions from mobile devices at base station locations surrounding the mobile device and estimate the location of the mobile device with respect to the base stations. Because the geographic location of the base stations is known, the determination of the location of the mobile device with respect to the base station permits the geographic location of the mobile device to be determined. The RF measurements of the transmitted signal at the base stations can include the time of arrival, the angle of arrival, the signal power, or the unique/repeatable radio propagation path (radio fingerprinting) derivable features. In addition, the geolocation systems can also use collateral information, e.g., information other than that derived for the RF measurement to assist in the geolocation of the mobile device, i.e., location of roads, dead-reckoning, topography, map matching, etc.

In a network-based geolocation system, the mobile device to be located is typically identified and radio channel assignments determined by (a) monitoring the control information transmitted on radio channel for telephone calls being placed by the mobile device or on a wireline interface to detect calls of interest, i.e., 911, (b) a location request provided by a non-mobile device source, i.e., an enhanced services provider. Once a mobile device to be located has been identified and radio channel assignments determined, the location determining system is first tasked to determine the geolocation of the mobile device and then directed to report the determined position to the requesting entity or enhanced services provider.



The monitoring of the RF transmissions from the mobile device or wireline interfaces to identify calls of interest is known as "tipping", and generally involves recognizing a call of interest being made from a mobile device and collecting the call setup information. Once the mobile device is identified and the call setup information is collected, the location determining system can be tasked to geolocate the mobile device.

While the above-described systems are useful in certain situations, there is a need to streamline the process in order to efficiently and effectively handle the vast amount of data being sent between the wireless communications network and the large number of mobile devices for which locations are to be determined. In this regard, the present subject matter overcomes the limitations of the prior art by estimating the location of a wireless mobile device using, at least in part, one or more pre-existing Network Measurement Reports ("NMRs") which include calibration data for a number of locations within a geographic region. The calibration data for these locations must be gathered and analyzed so that particular points (e.g., "grid points") within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. Then, the received signal level measurements reported by the mobile device to be geolocated may be compared with the data associated with the various grid points to estimate the location of the mobile device. The performance of a grid-based pattern matching system such as that disclosed herein is typically dependent on stored received signal level measurements that accurately reflect the levels that are likely to be reported by the mobile device to be located. These grid points do not necessarily have to be part of a uniform grid and usually will not be uniformly distributed throughout the geographic region. These non-uniform grid points ("NUGs"), once determined, can be assigned geographic coordinates so that the NUGs may be used in determining the location of a mobile device exhibiting certain attributes as discussed in more detail below.

Accordingly, an embodiment of the present subject matter provides a method for assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device where the method provides calibration data for each of one or more calibration points in the geographic region and where for each of the calibration points the associated calibration data is evaluated and based on that evaluation a determination is made as to whether at least one grid point should be defined, and if so, geographical coordinates are assigned to the grid point.

An additional embodiment of the present subject matter further includes in the above method a determination of geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region and for each of the grid points determining a closest node from the plurality of nodes and assigning characteristic data associated with the grid point to the closest node.

A further embodiment includes a method of assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device where calibration data for each of one or more calibration points in the geographic region are provided, and where for the calibration data associated with each of the calibration points the calibration data is evaluated, a determination is made based on the evaluation as to whether at least one grid point should be defined, and geographical coordinates are assigned to the grid point.

In another embodiment of the present subject matter, a system for assigning geographical coordinates to a grid point located in a geographic region is presented where the system includes a database and a processor for receiving calibration data for each of one or more calibration points in the geographic region and for each of the calibration points the processor is programmed to evaluate the associated calibration data, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the at least one grid point, and populate the database with the geographical coordinates.

A further embodiment of the present subject matter includes in the above system circuitry for determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region, and circuitry for determining, for each of the at least one grid point, a closest node from the plurality of nodes and assigning characteristic data associated with the grid point to the closest node.

Yet another embodiment of the present subject matter provides a method of locating a mobile device. The method comprises the steps of providing a plurality of grid points in a geographic region, providing a plurality of network measurement reports for a mobile device in the geographic region, and comparing ones of the plurality of grid points to at least one parameter of ones of the plurality of network measurement reports. The method further includes generating a first location estimate of the mobile device for each of the ones of said plurality of network measurement reports, and determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates. An additional embodiment includes the step of identifying and omitting outlier first location estimates by determining a Mahalanobis distance from each first location estimate to the second location estimate, determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and determining a third location estimate by averaging two or more of said first location estimates. Another embodiment may also interpolate between ones of the plurality of grid points when more than one grid point corresponds to the at least one parameter of the plurality of network measurement reports. An additional embodiment may provide a default location for the second location estimate if a second location estimate cannot be determined as a function of at least one of the generated first location estimates.

An additional embodiment of the present subject matter provides a method of improving a location estimate of a mobile device. The method comprises the steps of providing a plurality of grid points in a geographic region, providing a set of network measurement reports for a mobile device in the geographic region, the set of network measurement reports including one or more subsets of network measurement reports, and comparing ones of the plurality of grid points to at least one parameter of a subset of the network measurement reports. The method further includes generating a first location estimate of the mobile device for each subset of network measurement reports, determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates, and indicating an attribute of the second location estimate as a function of a parameter of a subset of the network measurement reports.

Another embodiment of the present subject matter provides a method of locating a mobile device in a geographic region. The method comprises the steps of providing a plurality of grid points in a geographic region, each of the grid points including at least one characterizing parameter and each of the grid points located on a grid defined over the geographic region and providing a plurality of network measurement reports for a mobile device in the geographic region. The method also comprises determining an estimated location for the mobile device from one network measurement report as a function of the at least one parameter.

An additional embodiment of the present subject matter provides a method of locating a mobile device in a geographic region. The method comprises the steps of providing a plurality of grid points in a geographic region, each of the grid points including at least one characterizing parameter and each of the grid points located on a grid defined over the geographic region and providing a plurality of network measurement reports for a mobile device in the geographic region. The method also comprises determining an estimated location for the mobile device from a set of said plurality of network measurement reports as a function of the parameter.

Yet another embodiment of the present subject matter provides another method of estimating the location of a mobile device in a geographic region. The method comprises the steps of providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes at least one characterizing parameter. A candidate network measurement report or set of network measurement reports may be received from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The method further comprises defining a first region as a function of a first characterizing parameter and a predetermined range of said first parameter. A second region may be defined as a function of another characterizing parameter and a predetermined range of another parameter. These steps may be repeated for each characterizing parameter in the calibration data and an intersection of each defined region determined. The location of a mobile device may then be estimated in the geographic region as a function of the intersection.

In a further embodiment of the present subject matter, a method of estimating the location of a mobile device in a geographic region is provided. The method may comprise the steps of providing one or more sets of calibration data for a plurality of calibration points in a geographic region where the calibration data includes at least one characterizing parameter and for each of select ones of the calibration points the calibration data includes plural data vectors. The method may also include receiving a candidate network measurement report or set of network measurement reports from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The method also includes defining a first region as a function of a first characterizing parameter and a predetermined range of the first parameter for a select one set of calibration data, and for the set of calibration data, defining a second region as a function of another characterizing parameter and a predetermined range of the another parameter. These steps may be repeated for each characterizing parameter in the set of calibration data and a clustering of the plural

data vectors may be determined. The location of a mobile device may be estimated in the geographic region as a function of the clustering.

Another embodiment of the present subject matter provides a method of estimating the location of a mobile device in a geographic region comprising providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes at least one characterizing parameter and receiving a set of network measurement reports from a mobile device at an unknown location where at least one of the network measurement reports in the set also includes at least one characterizing parameter. The method may also comprise determining a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set and determining one or more representative network measurement reports as a function of the representative value. The method may then estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports.

One embodiment of the present subject matter provides a system for estimating the location of a mobile device in a geographic region comprising a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region, the calibration data having at least one characterizing parameter and receiving a candidate network measurement report or set of network measurement reports from a mobile device at an unknown location, where the network measurement report also includes at least one characterizing parameter. The processor may be programmed to determine a first region as a function of a first characterizing parameter and a predetermined range of the first parameter and repeat the determination for each characterizing parameters in the calibration data. The processor may be further programmed to determine an intersection for each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

Another embodiment of the present subject matter provides a system for estimating the location of a mobile device in a geographic region comprising a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also receive a set of network measurement reports from a mobile device at an unknown location, at least one of the network measurement reports in the set may also include at least one characterizing parameter. The processor may be programmed to determine a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set, determine one or more representative network measurement reports as a function of the representative value, and estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports.

One embodiment of the present subject matter provides a method of determining the location of a mobile device in a geographic region. The method may comprise providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes one or more characterizing parameters and generating one or more sets of grid points for the calibration data. At least one network measurement report may be received from a mobile device at an unknown location and the network measurement report may be evaluated with each of the sets of grid points as a function of select ones of the characterizing parameters. A set of grid points may be selected as a function of a predetermined criteria, and the location of a mobile device in the geographic region may be determined as a function of the selected set of grid points. Additionally, the final estimated location may also be determined as a function of the estimated locations determined within each of the individual sets of grid points.

Another embodiment of the present subject matter includes a system for determining the location of a mobile device in a geographic region. The system comprises a database and a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in the geographic region where the calibration data and network measurement report include at least one characterizing parameter. The processor may be programmed to generate one or more sets of grid points for the calibration data and evaluate the at least one network measurement report with each of the sets of grid points as a function of select ones of the characterizing parameters. The processor may further be programmed to select a set of grid points as a function of a predetermined criteria, and determine the location of a mobile device in the geographic region as a function of the selected set. Additionally, the final estimated location may also be determined as a function of the estimated locations determined within each of the individual sets of grid points.

These embodiments and many other objects and advantages thereof will be readily apparent to one skilled in the art to which the invention pertains from a perusal of the claims, the appended drawings, and the following detailed description of the embodiments.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a flow chart for a method for assigning geographical coordinates according to an embodiment of the present subject matter.

FIG. **2** is a flow chart for a method for assigning geographical coordinates including a calibration point according to an embodiment of the present subject matter.

FIG. **3** is a flow chart for a method for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter.

FIG. **4** is a flow chart for a method for assigning geographical coordinates including clustering of data according to an embodiment of the present subject matter.

FIG. **5** is a flow chart for a method for assigning geographical coordinates including clustering of data vectors according to an embodiment of the present subject matter.

FIG. **6** is a flow chart for a method for assigning geographical coordinates including clustering according to an embodiment of the present subject matter.

FIG. **7** is a flow chart for a method for assigning geographical coordinates including determining outliers according to an embodiment of the present subject matter.

FIG. **8** is a flow chart for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter.

FIG. **9** is a flow chart for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter.

FIG. **10** is a flow chart for a method for assigning geographical coordinates to a grid point according to an embodiment of the present subject matter.

FIG. **11** is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where only one calibration point is in a geographic region according to an embodiment of the present subject matter.

FIG. **12** is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where there are plural calibration points in a geographic region according to an embodiment of the present subject matter.

FIG. **13** is a flow chart for a method for assigning geographical coordinates including calibration data information according to an embodiment of the present subject matter.

FIG. **14** is a flow chart for a method for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter.

FIG. **15** is a flow chart for a method for assigning geographical coordinates including populating a database with the geographical coordinates according to an embodiment of the present subject matter.

FIG. **16** is a flow chart for a method for assigning geographical coordinates including database information according to an embodiment of the present subject matter.

FIG. **17** is a flow chart for a method for assigning geographical coordinates including determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter.

FIG. **18** is a flow chart for a method for assigning geographical coordinates including characteristic data to nodes of uniform grid according to an embodiment of the present subject matter.

FIG. **19** is a flow chart for a method for assigning geographical coordinates for calibration data for each of one or more calibration points in a geographic region according to an embodiment of the present subject matter.

FIG. **20** is a block diagram for a system for assigning geographical coordinates according to an embodiment of the present subject matter.

FIG. **21** is a block diagram for a system for assigning geographical coordinates including a determination of clustering of plural data vectors according to an embodiment of the present subject matter.

FIG. **22** is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from different calibration points according to an embodiment of the present subject matter.

FIG. **23** is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from the same calibration point according to an embodiment of the present subject matter.

FIG. **24** is a block diagram for a system for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter.

FIG. **25** is a block diagram for a system for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter.

FIG. **26** is a block diagram for a system for assigning geographical coordinates including information for populating a database according to an embodiment of the present subject matter.

FIG. **27** is a block diagram for a system for assigning geographical coordinates including circuitry for determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter.

FIG. **28** is a block diagram for a system for assigning geographical coordinates including characteristic data according to an embodiment of the present subject matter.

FIG. **29** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter.

FIG. **30** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates.

FIG. **31** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter.

FIG. **32** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including omitting a first location estimate.

FIG. **33** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including interpolating between grid points.

FIG. **34** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including interpolating between grid points and/or assigning weights to selected grid points.

FIG. **35** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including providing a default location.

FIG. **36** is a flow chart for a method of improving a location estimate of a mobile device.

FIG. **37** is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter.

FIG. **38** is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter including omitting a first location estimate.

FIG. **39** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates.

FIG. **40** is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter.

FIG. **41** is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter including providing a default location.

FIGS. **42-55** are flow charts for methods of locating a mobile device in a geographic region according embodiments of the present subject matter.

FIGS. **56-64** are flow charts for methods of estimating the location of a mobile device in a geographic region according to embodiments of the present subject matter.

FIGS. **65-66** are diagrams for systems for estimating the location of a mobile device in a geographic region according to embodiments of the present subject matter.

FIGS. **67-69** are flow charts for methods of determining the location of a mobile device in a geographic region according to embodiments of the present subject matter.

FIGS. **70-72** are diagrams for systems for determining the location of a mobile device in a geographic region according to embodiments of the present subject matter.

## DETAILED DESCRIPTION

With reference to the Figures where generally like elements have been given like numerical designations to facilitate an understanding of the present subject matter, the vari-

ous embodiments of a system and method for generating a location estimate using uniform and non-uniform grid points are herein described.

The following description of the present subject matter is provided as an enabling teaching of the present subject matter and its best, currently-known embodiment. Those skilled in the art will recognize that many changes can be made to the embodiments described herein while still obtaining the beneficial results of the present subject matter. It will also be apparent that some of the desired benefits of the present subject matter can be obtained by selecting some of the features of the present subject matter without utilizing other features. Accordingly, those who work in the art will recognize that many modifications and adaptations of the present subject matter are possible and may even be desirable in certain circumstances and are part of the present subject matter. Thus, the following description is provided as illustrative of the principles of the present subject matter and not in limitation thereof. While the following exemplary discussion of embodiments of the present subject matter may be directed primarily towards calibration data, it is to be understood that the discussion is not intended to limit the scope of the present subject matter in any way and that the principles presented are equally applicable to other types of data, e.g., signal strength, GPS, NMR, Cell-ID, TDOA, RTT, TA, AOA, etc., capable of being delivered by components in a communications network such as a base station, location measurement unit, other mobile devices, etc. In addition, the use of various combinations of all of these sources, as in a hybrid location scheme, is within the scope of the subject matter disclosed herein.

The present subject matter is directed generally to the problem of estimating the location of a wireless mobile device using calibration data contained in one or more Network Measurement Reports ("NMRs"). The calibration data for various points must be gathered and analyzed so that particular points (e.g., "grid points") within the geographic region can be determined and associated with a particular set or sets of calibration data from, for example, one or more NMRs. In order to do so geographic coordinates may be assigned to grid points located in a geographic region. The grid points may be non-uniformly spaced throughout the geographic region and hence may be referred to as non-uniform grid points ("NUGs"). The location of a wireless mobile device may be estimated by comparing data reported by the mobile device to be geolocated with the data (and more particularly the characteristics derived from this data) associated with the various grid points to thereby estimate the location of the mobile.

The system and/or method of the present subject matter may apply to the situation where calibration data is available over discrete points in a 2-dimensional region "R" (3-D region is also contemplated such as within large multi-level structures). The calibration data may be contained within a Network Measurement Report ("NMR") as is known in the art or the calibration data may be obtained using other known methods. The calibration data may be obtained at each of several calibration points, which may be discrete points within region R each having geographical coordinates (e.g., latitude and longitude) associated therewith. The calibration data may include, but is not limited to, the following: (a) signal strengths observed for signals transmitted by a set of transmitters of known location within or in proximity to the region R; (b) signal strength of a transmitter located at the calibration point as measured by a set of receivers of known location within or in proximity to the region R; (c) round trip time for a signal between the calibration point and an external known point; (d) time difference of arrival at the calibration point with respect pairs of external points located within or in proximity to region R as measured by either a receiver at the calibration point or the external points; (e) the serving cell or sector for a mobile wireless device operating at that calibration point; (f) the network state at the time of collection—a finite number of such states may be required to distinguish between network conditions that vary diurnally, weekly or in some other manner; and (g) combinations of the above.

As a non-limiting example, the case in (a) may apply to the Integrated Digital Enhanced Network ("IDEN") specification, (c) may apply to the Global System for Mobile communications ("GSM") specification as in the Timing Advance ("TA") parameter or the Round Trip Time ("RTT") parameter in the Universal Mobile Telecommunications System ("UMTS") specification, (d) may apply to the UMTS specification, while the external receivers may be the base stations. In general, the calibration data may be any of those measurements made by a mobile wireless device located at the calibration point or any measurement made on the transmissions or characteristics of the mobile wireless device at a set of external transmitter/receivers in the region R or in proximity thereto.

The calibration data may consist of many such sets (i.e., vectors) obtained at one or more calibration points. At each calibration point, the data gathering may have resulted in either a single data vector or multiple data vectors, so that there are potentially multiple sets of data and/or data vectors associated with each calibration point.

A NUG generator or a method to produce NUGs may begin the NUG generation operation using, for example, one of more of the following: (a) a fixed uniform grid ("UG") defined over the region R with the calibration point data being assigned to the fixed grid points by some rule (e.g., allocated by closest fixed grid point, a centroid of a set of fixed grid points, etc.); (b) random grid points to define the start of each NUG; (c) combinations of (a) and (b) depending on the characteristics of the calibration data; or (d) some other useful method.

In any of these cases, the NUG generator may evaluate the data vectors at a particular (candidate) calibration point, or at a fixed grid point to which the data vector(s) is/are assigned. This calibration point or grid point may serve as the root of a first NUG. The root of the NUG may be the calibration data vector that initiates the creation of that NUG. The vectors may be examined using, for example, increasingly stringent tests of statistical sufficiency. In particular, a determination may be made as to whether the data vectors exhibit clustering. If the data exhibits tight clustering, the data for the next candidate calibration point may be aggregated to the former calibration point and the clustering property may be re-evaluated. For example, if the second calibration point also has a cluster but this cluster is sufficiently different than the cluster of the first calibration point, a determination may be made that the data for the two considered calibration points should be allocated to the roots of separate NUGs. If the aggregate cluster (i.e., a cluster including data from both the first and second calibration points) is statistically very similar to either of the first or second clusters (taken independently), then the data for the two calibration points may be allocated to the same NUG. All adjacent calibration data points may be similarly evaluated with respect to the first considered calibration point. Thus one or more of the adjacent calibration points may either wind up having all their data accumulated into a single NUG or, at the other extreme, each such calibration point may become the root of a separate NUG.

The primary test made to determine the allocation may be one of a variety of clustering tests, such as, for example, the

K-means algorithm. Statistical similarity may be determined by, for example, the probability density function ("pdf") of the data parameters (e.g., neighboring cell signal levels, timing information, etc.), the mean and variance of the data parameters, the serving cell/sector, or other functions of the calibration data.

Those measurements or parameter values that do not cluster may be referred to as outliers. The performance of a grid-based pattern matching system such as that disclosed herein is typically dependent on stored received signal level measurements that accurately reflect the levels that are likely to be reported by the mobile device to be located. If the drive test data, for example, used to create the RF signal level grid contains outlier measurements, the statistically consistent value of the signal level will be distorted. Therefore, the present subject matter also describes a system and method used to identify and eliminate outlier signal level measurements and timing advance values (or in general, any parameter within the NMR) during NUG or grid creation so as to improve the estimate of the mean parameter value.

As a non-limiting example, in a very simple consideration of clustering one could consider the mean value of a parameter. In this scenario, neighbor cell control channel signal level measurement outliers could be eliminated as follows: At each grid point, the average received signal level of a particular control channel signal may be computed from all of the measurements of that signal assigned to the grid point. The deviation of each individual measurement from the mean may be computed. Measurements that deviate by more than a configurable predetermined threshold from the mean may be omitted. The average may then be recomputed without the omitted outliers. In a scenario where there are very few measurements, typically less than five or so, the original mean value will be greatly influenced by any outlier measurements and thus may falsely identify too many of the measurements as outliers, or fail to detect outliers at all. For this reason, another parameter is used to only perform the outlier check if there are at least a minimum number of measurements.

In a more general case, a cluster may be a region in N-dimensional NMR vector space where there is a sufficient number of such vectors with a mutual variation such that the mutual variation could be ascribed purely to noise in the measurement. Thus, for example, if within a few feet of the original measurement, if a particular parameter is blocked (say by a large structure such as a building) that parameter would fall out of the original cluster. If sufficient such blocked locations have data falling near the original cluster, one may obtain a secondary cluster where the difference between the first and second clusters is the large variation in this particular parameter.

In addition, if any of the examined sets of data associated with a calibration point exhibit more than one cluster, it may be necessary to define one or more co-located NUGs. Thus, if there are, for example, three well defined clusters associated with a particular calibration point, these clusters could form the roots of three co-located NUGs. The data in these NUGs may grow depending on whether similar clusters can also be found in adjacent (or close) calibration points in which case the similar clusters may be aggregated to the original NUGs or, if the adjacent clusters are not similar, the adjacent clusters (or cluster) may form separate root NUGs (or NUG).

Further, if the quantity of data associated with a particular calibration point is insufficient to sensibly test for statistical similarity or clustering, data from adjacent calibration grid points may be accumulated first and the statistical or clustering test performed thereafter. Thus, based on the results of the clustering test using the accumulated data the determination of how one should separate out the data into NUGs may be made.

The technique may be repeated until all calibration grid points in the region R are exhausted. At the end of this process one has divided the region into a collection of NUGs, where multiple co-located NUGs may exist. The NUGs may fully cover the region R and each NUG may have statistically similar data accumulated into itself. The geometrical shape (i.e., the shape defined by the union of locations of calibration points assigned to the NUG) and the amount of data accumulated into such NUGs is seen to be variable since these are determined by the statistical similarity of the data allocated to a NUG.

Additionally, we may also consider the method of generating NUGs based not on statistical consistency of calibration data, but on other conditions such as (a) a minimum number of unique neighbors observed in data accumulated from allocated calibration grid points; (b) a minimum number of data vectors (NMRs); (c) a maximum and/or minimum NUG radius; (d) a specific set of neighboring cells; (e) a specific set of neighboring cells with power ordering; or (f) any combination of the above. Additionally, the method of using statistical consistency or similarity or data clustering combined with any of these other conditions may be employed.

For each so obtained NUG, a variety of parameters and functions may be generated and stored to describe that NUG. These are termed the NUG characteristics. The NUG characteristics are a representation in that attempt to capture the nature and variability of the data associated with that NUG in a compact and representative form. These characteristics may include, but are not limited to, the following: (a) an ordered list of neighboring cells; (b) functions defined on the absolute neighboring cell power levels (e.g., mean, median, $k^{th}$ moment, cluster-mean, etc.); (c) functions defined on the relative neighboring cell power differences (e.g., mean, median, $k^{th}$ moment, cluster-mean, etc.); (d) serving cell/sector; (e) timing advance parameter (or equivalent); (f) individual pdf (probability density function or probability distribution function) of each neighboring cell power level; (g) joint pdf of neighboring cell power levels; (h) mean and variance of neighboring cell power levels; (i) mobile device orientation (e.g., indoors, outdoors, direction mobile device is facing (e.g., North, South, etc.), tilted upwards, azimuth, elevation, etc.); (j) a compact and/or efficient representation that enables retrieval of the calibration data NMR vectors assigned to this NUG; (k) the network state as indicated in the calibration data; (l) a confidence measure indicative of the reliability of the calibration data feeding this NUG; and (m) any combinations of the above.

If a pdf is determined for a NUG, that pdf may be generated using either the Parzen technique or the method of Gaussian mixtures or some variant thereof. In addition when a need to specify the variance or covariance exists, that parameter may be set to a value dependent on the observed variance for a particular neighboring cell power level or the observed covariance matrix for a set of neighboring cell power levels.

The location ascribed to the NUG may be, for example, any internal point within the NUG. If the NUG contains only a single calibration point, the location of the NUG may be set as the location of the calibration point. If the NUG encompasses several calibration points, the location of any one of the calibration points or the centroid of such calibration points or some other similar measure may be used to define the NUG location. Also, in the case of multiple co-located NUGs, all such NUGs may have their assigned location set to the same value.

With reference now to FIG. **1**, a flow chart is depicted for a method for assigning geographical coordinates according to an embodiment of the present subject matter. At block **101**, calibration data may be provided for each of one or more calibration points in a geographic region. At block **102**, for each of the calibration points calibration data associated with the calibration point is evaluated and a determination is made as to whether a grid point, such as a NUG, should be defined. If it is determined that a grid point is to be defined, geographical coordinates are assigned to the grid point so that the grid point may be useful in estimating the location of a mobile device.

FIG. **2** is a flow chart for a method for assigning geographical coordinates including a calibration point according to an embodiment of the present subject matter. Blocks **201** and **202** are similar to blocks **101** and **102**, respectively. At block **213**, the calibration point may be located on a predetermined fixed uniform grid defined over the geographic region or the calibration point may be randomly located within the geographic region.

FIG. **3** is a flow chart for a method for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter. Blocks **301** and **302** are similar to blocks **101** and **102**, respectively. At block **313**, the calibration data associated with one or more calibration points may be comprised of information from a NMR, or the calibration data for a particular calibration point may be obtained from one or more mobile devices located at or in close proximity to the calibration point, or the calibration data for a particular calibration point may be obtained from a signal transmitted from a mobile device (or devices) located at or in close proximity to the calibration point where the signal is received by a receiver in or in proximity to the geographic region.

FIG. **4** is a flow chart for a method for assigning geographical coordinates including clustering of data according to an embodiment of the present subject matter. Blocks **401** and **402** are similar to blocks **101** and **102**, respectively. At block **413**, for one or more of the calibration points the calibration data may include multiple data vectors and, at block **414**, the evaluation of the data vectors may include a determination of clustering of the multiple data vectors as described above.

Considering now the flow chart depicted in FIG. **5**, the flow chart indicates a method for assigning geographical coordinates including clustering of data vectors according to an embodiment of the present subject matter. Blocks **501** and **502** are similar to blocks **101** and **102**, respectively. At block **503**, the determination of whether at least one grid point should be defined based on the evaluation of the calibration data associated with a calibration point includes a comparison of a first cluster of data vectors from a first calibration point to a second cluster of data vectors where the second cluster of data vectors includes the first cluster of data vectors as well as data vectors from a second calibration point. At block **504**, if the comparison in block **503** results in the difference between the first and second cluster of data vectors being within a predetermined tolerance value, then the data vectors from the first and second calibration points are assigned to the same grid point. However, if the comparison is not within tolerance, then the data vectors from the first calibration point are assigned to a first grid point and the data vectors from the second calibration point are assigned to a second grid point.

The flow chart shown in FIG. **6** illustrates another method for assigning geographical coordinates including clustering according to an embodiment of the present subject matter. Here, blocks **601**, **602**, **603**, and **604** are similar to blocks **501**, **502**, **503**, and **504**, respectively. At block **615** the evaluation of calibration data for one or more calibration points may include determining the clustering of plural data vectors using a K-means analysis. At block **616** the comparing of clusters of data vectors may include determining a probability density function of an aspect of the data vectors.

FIG. **7** is a flow chart for a method for assigning geographical coordinates including determining outliers according to an embodiment of the present subject matter. Blocks **701**, **702**, **713**, and **714** are similar to blocks **401**, **402**, **413**, and **414**, respectively. At block **703**, a determination of outlier data vectors may be made and the outlier data vectors may be eliminated from the determination of data vector clustering.

Regarding FIG. **8**, a flow chart is represented for a method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter. Blocks **801** and **802** are similar to blocks **101** and **102**, respectively. At block **803**, the determination if at least one grid point should be defined based on the evaluation of calibration data may include a comparison of a first cluster of data vectors associated with a first calibration point to a second cluster of data vectors associated with the first calibration point. If the result of the comparison is within a predetermined tolerance, then the data vectors from the first and second clusters may be assigned to the same grid point; otherwise, the data vectors from the first cluster may be assigned to a first grid point while the data vectors from the second cluster may be assigned to a second grid point.

FIG. **9** is a flow chart illustrating another method for assigning geographical coordinates including clustering of data vectors at the same calibration point according to an embodiment of the present subject matter. Here, blocks **901**, **902**, **903**, and **904** are similar to blocks **801**, **802**, **803**, and **804**, respectively. At block **915** the geographical coordinates assigned to the first and second grid points may be identical.

Directing attention now towards FIG. **10**, a flow chart is presented for a method for assigning geographical coordinates to a grid point according to an embodiment of the present subject matter. Blocks **1001** and **1002** are similar to blocks **101** and **102**, respectively. At block **1013**, the geographical coordinates assigned to a first grid point may be different than the geographical coordinates assigned to a second grid point or the geographical coordinates assigned to a first grid point may be the same as the geographical coordinates assigned to a second grid point.

FIG. **11** is a flow chart for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where only one calibration point is in a geographic region according to an embodiment of the present subject matter. Blocks **1101** and **1102** are similar to blocks **101** and **102**, respectively. At block **1113**, if there is only one calibration point within the geographic region, then the geographical coordinates assigned to a grid point may result in the grid point being located within a predetermined radius of the one calibration point. Or, the geographical coordinates assigned to a grid point may be identical to the geographical coordinates of the calibration point.

Moving now to FIG. **12**, a flow chart is shown for a method for assigning geographical coordinates including assigning geographical coordinates to a grid point where there are plural calibration points in a geographic region according to an embodiment of the present subject matter. Blocks **1201** and **1202** are similar to blocks **101** and **102**, respectively. At block **1213**, where there are multiple calibration points in the geographic region, the geographical coordinates assigned to a grid point may result in the grid point being located within a

predetermined radius of a centroid of a polygon formed by connecting the multiple calibration points.

FIG. **13** is a flow chart for a method for assigning geographical coordinates including calibration data information according to an embodiment of the present subject matter. Blocks **1301** and **1302** are similar to blocks **101** and **102**, respectively. At block **1313**, the calibration data may include one or more of the following: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at a calibration point; signal strength of a signal transmitted by a transmitter located at a calibration point as received by a receiver at a known location; round trip time for a signal traveling between a calibration point and a known location; timing advance of a signal received by a mobile device at a calibration point; time difference of arrival of plural signals at a calibration point with respect to a pair of known locations as measured by a receiver at a calibration point or at the known locations; the identification of a serving cell or serving sector of a mobile device located at a calibration point; a state of a wireless network serving a mobile device, and combinations thereof.

FIG. **14** is a flow chart for a method for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter. Blocks **1401** and **1402** are similar to blocks **101** and **102**, respectively. At block **1413**, the evaluating of the calibration data associated with a calibration point may include an evaluation such as: a minimum number of unique neighboring calibration points as determined by calibration data of the neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum radius from a calibration point; a predetermined set of cells neighboring a cell serving a mobile device; and combinations thereof.

FIG. **15** is a flow chart for a method for assigning geographical coordinates including populating a database with the geographical coordinates according to an embodiment of the present subject matter. Blocks **1501** and **1502** are similar to blocks **101** and **102**, respectively. At block **1503**, a database may be populated with the geographical coordinates assigned to the grid points.

FIG. **16** is a flow chart for a method for assigning geographical coordinates including database information according to an embodiment of the present subject matter. Blocks **1601**, **1602**, and **1603** are similar to blocks **1501**, **1502**, and **1503**, respectively. At block **1604**, the database may be populated with information such as: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

Directing attention now to FIG. **17**, a flow chart is presented for a method for assigning geographical coordinates including determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter. Blocks **1701** and **1702** are similar to blocks **101** and **102**, respectively. At block **1703**, geographical coordinates may be determined for the nodes of a uniform grid spanning the geographic region. At block **1704**, for each of the grid points, a determination of the closest node of the uniform grid is made and the characteristic data associated with the grid point may be assigned to the closest node.

Further, FIG. **18** is a flow chart for a method for assigning geographical coordinates including characteristic data to nodes of uniform grid according to an embodiment of the present subject matter. Here, blocks **1801**, **1802**, **1803**, and **1804** are similar to blocks **1701**, **1702**, **1703**, and **1704**, respectively. At block **1805**, the characteristic data may include a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

With reference to FIG. **19**, a flow chart is illustrated for a method for assigning geographical coordinates for calibration data for each of one or more calibration points in a geographic region according to an embodiment of the present subject matter. At block **1901**, calibration data may be provided for each of one or more calibration points in a geographic region. At block **1902**, for the calibration data for each of the calibration points in the geographic region, the calibration data is evaluated and a determination is made as to whether a grid point should be defined based on the evaluation. If it is determined that a grid point is to be defined, geographical coordinates are assigned to the grid point so that the grid point may be useful in estimating the location of a mobile device.

With attention now directed to FIG. **20**, a block diagram is presented that represents a system for assigning geographical coordinates according to an embodiment of the present subject matter. A database **2001** is operatively connected to a processor **2002**. The processor **2002** is capable of receiving calibration data for each of one or more calibration points in a geographic region. The processor **2002** may be programmed, as shown in block **2003**, to evaluate the calibration data associated with the calibration points, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the one or more grid points, and populate the database **2001** with the geographical coordinates.

FIG. **21** is a block diagram for a system for assigning geographical coordinates including a determination of clustering of plural data vectors according to an embodiment of the present subject matter. The database **2101**, the processor **2102**, and block **2103** are similar to the database **2001**, the processor **2002**, and block **2003**, as described above, respectfully. At block **2114**, for each of select ones of the calibration points, the calibration data may include multiple data vectors and the evaluating of the calibration data may include a determination of clustering of the multiple data vectors.

FIG. **22** is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from different calibration points according to an embodiment of the present subject matter. The database **2201**, the processor **2202**, block **2203**, and block **2214** are similar to the database **2101**, the processor **2102**, block **2103**, and block **2114**, as described above, respectfully. At block **2215**, the determination if at least one grid point should be defined based on the evaluation may include comparing a first cluster of data vectors from a first one of the select calibration points to a second cluster of data vectors, where the second cluster of data vectors may include the first cluster of data vectors and data vectors from a second one of the select calibration points. At block **2216**, if the result of the comparison is within a predetermined tolerance, then the data vectors from the first

and second calibration points may be assigned to the same grid point; otherwise, the data vectors from the first calibration point may be assigned to a first grid point and the data vectors from the second calibration point may be assigned to a second grid point.

FIG. **23** is a block diagram for a system for assigning geographical coordinates including comparing clusters of data vectors from the same calibration point according to an embodiment of the present subject matter. The database **2301**, the processor **2302**, block **2303**, and block **2314** are similar to the database **2101**, the processor **2102**, block **2103**, and block **2114**, as described above, respectfully. At block **2315**, the determination if at least one grid point should be defined based on the evaluation may include comparing a first cluster of data vectors from a first one of the select calibration points to a second cluster of data vectors from the first one of the select calibration points. At block **2316**, if the result of the comparison is within a predetermined tolerance, then the data vectors from the first and second calibration points may be assigned to the same grid point; otherwise, the data vectors from the first cluster may be assigned to a first grid point and the data vectors from the second cluster may be assigned to a second grid point.

Looking now at FIG. **24**, a block diagram is presented representing a system for assigning geographical coordinates including calibration data according to an embodiment of the present subject matter. The database **2401**, the processor **2402**, and block **2403** are similar to the database **2001**, the processor **2002**, and block **2003**, as described above, respectfully. At block **2414**, the calibration data may include: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at a calibration point; signal strength of a signal transmitted by a transmitter located at a calibration point as received by a receiver at a known location; round trip time for a signal traveling between a calibration point and a known location; timing advance of a signal received by a mobile device at a calibration point; time difference of arrival of multiple signals at a calibration point with respect to a pair of known locations as measured by a receiver at a calibration point or at the known locations; the identification of a serving cell or serving sector of a mobile device located at a calibration point; a state of a wireless network serving a mobile device, and combinations thereof.

FIG. **25** is a block diagram for a system for assigning geographical coordinates including evaluating calibration data according to an embodiment of the present subject matter. The database **2501**, the processor **2502**, and block **2503** are similar to the database **2001**, the processor **2002**, and block **2003**, as described above, respectfully. At block **2514**, the evaluation of the associated calibration data may include an evaluation such as: a minimum number of unique neighboring calibration points as determined by calibration data of the neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum radius from a calibration point; a predetermined set of cells neighboring a cell serving a mobile device; and combinations thereof.

FIG. **26** is a block diagram for a system for assigning geographical coordinates including information for populating a database according to an embodiment of the present subject matter. The database **2601** and the processor **2602** are similar to the database **2001** and the processor **2002**, as described above, respectfully. At block **2603**, the processor **2602** may be programmed to evaluate the calibration data associated with the calibration points, determine if at least one grid point should be defined based on the evaluation, assign geographical coordinates to the one or more grid points, populate the database **2601** with the geographical coordinates, and populate the database **2601** with information which may include: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

FIG. **27** is a block diagram for a system for assigning geographical coordinates including circuitry for determining geographical coordinates for nodes of a uniform grid according to an embodiment of the present subject matter. The database **2701**, the processor **2702**, and block **2703** are similar to the database **2601**, the processor **2602**, and block **2603**, as described above, respectfully. The system may further comprise circuitry **2704** for determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning the geographic region, and circuitry **2705** for determining, for each of the one or more grid points, a closest node from the plurality of nodes of the uniform grid and assigning characteristic data associated with each of the grid point to its closest node.

FIG. **28** is a block diagram for a system for assigning geographical coordinates including characteristic data according to an embodiment of the present subject matter. The database **2801**, the processor **2802**, block **2803**, circuitry **2804**, and circuitry **2805** are similar to the database **2701**, the processor **2702**, block **2703**, circuitry **2704**, and circuitry **2705**, as described above, respectfully. At block **2816**, the characteristic data may include: a list of cells neighboring a cell serving a mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving a mobile device; an identity of a cell or a sector serving a mobile device; a timing advance parameter; a geographical orientation of a mobile device; a location of a mobile device; network measurement report data vectors; a state of a network serving a mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

In a typical signal strength pattern matching mobile location system the time allowed to produce a location may be such that multiple NMRs and sets and subsets thereof may be available. By way of a non-limiting example, in the GSM air standard, mobile measurements are reported at an approximate rate of approximately two per second. Generally, the time allowed to produce a location may be on the order of thirty seconds. It is therefore an aspect of embodiments of the present subject matter to improve location accuracy by combining individual locations from calibration data, e.g., multiple NMRs, to produce a final location estimate.

Grid-based signal strength pattern matching location systems typically determine a quantitative measure of how close each candidate grid point matches with mobile-reported measurement parameters. An estimate of a mobile device's location may then be given by a grid point having the closest match thereto or a location interpolated between several grid point locations. As multiple NMRs are generally available during the time allotted to report the estimated location of a mobile device, embodiments of the present subject matter may utilize each NMR to generate an independent location estimate. These independent or individual location estimates may then be averaged or another mathematical function employed thereon to produce a final estimated mobile location that may be statistically more accurate.

Many location systems may also "fall back" to a default location as a function of the serving cell when the system is unable to determine a grid point match location. In such an instance, a location status variable may be utilized to identify the default location as a fall back location. Such a fall back location is generally less accurate than a location estimate determined by a pattern matching location system; however, an exemplary location combiner may omit any fall back locations and average or combine location estimates determined by an exemplary pattern matching algorithm.

A correlation may exist between location accuracy and mismatch distance metrics, e.g., "cost" values. The correlation may be exploited by flagging individual location estimates as having a high cost or metric (e.g., using a location status variable), and the corresponding location estimates are likely to possess a large location error. Embodiments of the present subject matter may present a refinement to the location combiner by skipping or omitting individual locations exceeding a predetermined "cost" threshold. Thus, the resulting location accuracy may be significantly improved. In further embodiments, the correlation between mismatch distance metrics and location accuracy may be exploited by employing weighted averaging of the individual estimated locations, weighting by an inverse of the metrics, normalizing by a sum of the inverses, or any combination thereof. A further metric that may be utilized for weighting the contribution of individual location estimates to a final location estimate may be the number of reporting neighboring cells. By way of a non-limiting example, assuming five individual location estimates are combined and four of the five individual location estimates possessed six reporting neighboring cells and the fifth location estimate possessed four reporting neighboring cells, the fifth location estimate may then be de-weighted in the final location estimation.

Another embodiment of the present subject matter may identify and omit outlier individual location estimates to improve the final location estimation. For example, a Mahalanobis distance from each individual location estimate to the final location estimate may be determined. A dynamic distance threshold may be determined from the median of these distances multiplied by a configurable factor. An individual location estimate having a distance to the final location estimate exceeding the threshold may be identified as an outlier. The final location estimate may then be re-determined with the outlier locations omitted. In the event that weighted averaging is utilized in such a determination, the weights may be re-determined prior to the final location estimation.

It may also be noted that estimated locations derived utilizing subsets of available NMRs may often differ. For example, considering an NMR including a set of ordered (e.g., in descending magnitude) reporting neighboring cell (NC) power levels, with the NC having an order ABCDE. If the lowest power NC (NC=E) is omitted from the NMR, the locations determined using ABCD NCs may be different from ABCDE. Similarly, the location determined for ABCE NCs may differ from that for ABDE NCs.

An examination or evaluation of the location estimates derived from subsets of the NMRs may provide an indication regarding the quality of the final location estimate. By way of a non-limiting example, if the location estimates derived utilizing any possible method of mapping the NMR or sets thereof to a specific geographic location or grid point, whether using NUGs or uniform grid points, agree under combinations of subsets, the confidence in the location estimate may be high and thus represent a confidence measure on the location estimate. Further, the fraction of total location estimates within a predetermined distance of the final location estimate may also qualify as a confidence measure.

In one embodiment of the present subject matter, for each NMR, one may form a set of all subsets of a selected NMR. Therefore, in a non-limiting example of an ordered set of NCs given by ABC, a full set of subsets is {ABC, AB, AC, BC, A, B, C}. In each case, an estimated location may be derived utilizing any method of location. Each of the locations in this set of locations, L, may possess an associated probability or other measure derived from the particular location method, thus defining a set M. A variety of schemes may be defined and implemented upon the set L and the set of associated measures on L, given by M, such as, but not limited to: (a) computing the final estimated location by clustering the set L without any reference to the measures in M; (b) computing the final estimated location as the centroid of a region containing the tightest cluster in L having an aggregate measure higher than some pre-set value; (c) computing the final estimated location as the location of the NUG (e.g., centroid of the NUG) which occurs most often in L; (d) computing the final estimated location by clustering the subset of L obtained by dropping the least power member in the NMR successively (e.g., the subset {ABC, AB, A}); (e) computing the final estimated location as the subset of L obtained by successively dropping the least power member in the NMR and with weighting by the corresponding measure in M.

Considering that the individual marginal probabilities for each NMR component, characteristic or parameter over a set of candidate NUGs or uniform grid points (UG) have been determined, it may be assumed that for every subset in L, the measure set M provides the joint probability for the subsets of the NMR. Using the subset AB in the previous example, the marginal probability for A, B and C over all NUGs has been determined. To determine the joint probability of A and B, for example, the marginal probabilities for A and B may be multiplied over the NUGs (or other locations). This generates the measure set M, and having the set L and set M defined, any one or combination of the methods in (a)-(e) described in the previous paragraph may be applied thereto for an estimation of an exemplary confidence measure.

The same principles may be applied to multiple NMRs and each of their respective subsets where each subset of each NMR may be assigned its respective measure in a now larger set M. It follows that the methods in (a)-(e) described above are equally applicable. In the case of multiple NMRs, a representative NMR may be determined through a clustering algorithm applied to each parameter of the NMR viewed over the set of NMRs. The methods in (a)-(e) described above may then be applied to this representative NMR for an estimation of an exemplary confidence measure.

It is also an aspect of embodiments of the present subject matter to provide an estimate of the location error in a signal strength pattern matching location system. As discussed above, a confidence measure may be determined that provides an indication of the quality of the location estimate.

In one embodiment of the present subject matter, if the final estimated location is an average of the individual locations, the degree to which the individual locations are clustered around the final estimation may provide an indication of the location error. The error estimate may be determined as the average of the distances from each individual location to the final estimated location as a function of the following relationship:

$$\hat{e} \equiv \frac{\sum_{i=1}^{N} d_i}{N} \tag{1}$$

where N is the number of estimated locations and $d_i$ is the Euclidean distance from the $i^{th}$ estimated location to the final estimated location.

The error estimate may also be determined as a function of the following relationship:

$$\hat{e} \equiv \frac{\sum_{i=1}^{N} w_i d_i}{\sum_{i=1}^{N} w_i} \tag{2}$$

where N is the number of estimated locations, $d_i$ is the Euclidean distance from the $i^{th}$ estimated location to the final estimated location, and $w_i$ is a series of weighting factors.

As discussed above, when subsets of available NMRs are considered, however, the estimated locations may also differ. Therefore, an exemplary confidence measure may also be defined upon an estimated location given by any function that increases as the number of subset locations agree with the final estimated location. A non-limiting example of such a function may be the fraction of total locations that agree with the final estimated location or the fraction of total locations that lie within a certain distance of the final estimated location. In a further embodiment, weights may be assigned to the location estimates by utilizing the parameters or functions employed in determining the estimated location to thereby weight the determination of the associated confidence measure. Further exemplary confidence measures may be a function of pdfs, distortion measures, Mahalanobis distances, etc. with respect to any one or sets of NUGs.

Exemplary weighting quantities, e.g., distortion measures, pdfs, etc., may also be derived while estimating any location from single and multiple NMRs or their subsets, and may also be utilized to estimate location error. Empirically, the magnitudes of these weighting quantities may be correlated with the expected error. This relationship may be established graphically or in tabular format as a function of environmental characteristics (e.g., urban, suburban, seasonal, etc.). As a result, given a set of weighting quantities, an associated error may be predicted for a specific location estimate.

In one embodiment of the present subject matter, if the set of derived locations utilizing a set and/or subset of NMRs exhibit clusters, cluster separation may be employed between the highest aggregate weighted clusters to define an expected error. Such a distance may be termed as an inverse confidence measure as the larger the distance becomes, the greater the chance of error in the final location estimate if the corresponding cluster were selected. It follows that if the aggregate weight for a distant cluster is small, this distance should be modified to de-weight the associated distance by the weight of the cluster. An exemplary determination may multiply the cluster distance by a ratio of the weight of a selected cluster to the weight of a distant cluster; however, many such variations of this fundamental idea are clearly conceivable and such an example should not limit the scope of the claims appended herewith.

In another embodiment of the present subject matter, when each of the individual location estimates are generally at the same location (e.g., each located at the same calibration or grid point) the resulting error estimate would be zero or near zero. In such a scenario, the error estimate may be bounded by a minimum error value such as, but not limited to, a configurable constant based upon the overall expected system accuracy (e.g., the 25th percentile of overall system error, etc.).

It should be noted that the statistical averaged or weighted averaged location accuracy improves as the number of individual location estimates averaged or determined increases. For example, a final location estimate that comprises the average of two individual locations may generally be less accurate than a final location estimate comprising an average of twenty individual location estimates. Further, the optimal number of location estimates to combine or consider is dependent upon several factors including, but not limited to, the speed of the mobile device, the rate of acquiring NMRs, etc. This relationship may also be utilized to improve the error estimate as the number of individual location estimates increases.

In embodiments of the present subject matter wherein any one or multiple individual location estimates are "fall back" locations (e.g., default locations that may be based upon serving cell identification location), a default error estimate may be determined based upon an expected statistical accuracy of cell identification location. This determination may be a function of cell site geometry in an associated or corresponding operating market and may also be determined empirically through accuracy testing. Exemplary scenarios in which default locations may be encountered include, but are not limited to, when the NMR does not contain any NC measurements, when the available set of NMRs for the mobile device location generates a set of candidate locations that does not cluster (e.g., when the individual location estimates appear to be randomly distributed over a geographic region), when an NMR has very few reporting NCs and the confidence measure is poor, and combinations thereof.

In embodiments of the present subject matter where NMR data may be missing or invalid, the coordinates of the cell serving a mobile device may be retrieved from a respective site database from the serving cell identifier. In this instance, an exemplary default location may be a location that is a configurable distance away from the serving site. The configurable distance may or may not be positioned at a heading along the serving sector azimuth. For air standards in which certain parameters (e.g., timing advance, round trip timing, etc.) are available, this data may also be converted to an approximate range estimate from the serving site and utilized with other applicable parameters. For example, when such parameters are available, the default location may be enhanced by selecting a location on the serving cell azimuth at a distance from the site given by a TA range estimate.

In embodiments of the present subject matter where an NMR may include Time Difference of Arrival ("TDOA") data, this parameter may be utilized to derive a region within the cell to constrain the default location. For example, the TDOA, assuming the base station time offsets are known, defines a hyperbola in the region of interest. An intersection of this hyperbola with the applicable TA region to this cell may be utilized as a default location estimate. Alternatively, a default location estimate may be employed that does not rely on a serving sector heading if there exists a priori knowledge of sector coverage density. For example, if a sector coverage region can be determined (e.g., through drive testing, etc.), then the centroid of the sector coverage region may be stored in the respective site database by sector for each site and retrieved as a default location.

A further aspect of embodiments of the present subject matter may also improve location accuracy by interpolating between grid point locations when more than one grid point matches the calibration or reported data within a predetermined value. Generally, grid-based signal strength pattern matching location systems determine a quantitative measure of how close each candidate grid point (e.g., NUG or UG) matches mobile device reported measurement parameters. The location estimate of the mobile device may be given by the grid point having a match within a predetermined range. Further, as the actual location of the mobile device is generally not constrained to lie at a grid point location, interpolation between grid points may result in a more accurate location estimate.

During an exemplary interpolation according to one embodiment of the present subject matter, an analysis of whether interpolation should be performed may be determined as well as a selection of the appropriate grid or calibration points for the interpolation. Distance metrics may also be determined on any number of grid points. Exemplary metrics are discussed above and may include, but are not limited to, pdfs, Mahalanobis distance between parameter vectors, ordering number between ordered NCs in the NMR, NUG, UG, and combinations thereof. By way of a non-limiting example, it may be assumed that the distance metric for each of N candidate grid points (N>1) is determined and sorted. Representing the distance metric as C, then for each $i^{th}$ candidate, i=1 . . . N, an appropriate metric may be determined by the following relationship:

$$C\_\text{Ratio}_i=[C_i-C_{min}]/[C_N-C_{min}] \tag{3}$$

where $C_i$ is a metric associated with an $i^{th}$ candidate grid point, $C_N$ is a metric associated with the worst corresponding candidate grid point, and $C_{min}$ is a metric associated with the best corresponding candidate grid point. It follows that grid points having a $C_{ratio}$ less than a predetermined and configurable threshold value may be a candidate for interpolation.

Generally, interpolation occurs between adjacent or nearby grid points. To minimize or prevent interpolation across widely spaced grid points, the distance from each interpolation candidate grid point to the minimum cost grid point may be less than a configurable distance threshold.

In embodiments when there are few grid point candidates or when there are fewer than a configurable number of candidate grid points, an appropriate metric may be determined by the following relationship:

$$C\_\text{Ratio}_i=[C_i-C_{min}]/[C_{min}] \tag{4}$$

where $C_i$ is a metric associated with an $i^{th}$ grid point and $C_{min}$ is a metric associated with the best corresponding grid point. Equation (4) may thus enable an identification of appropriate grid points for interpolation when N is small. Equation (4) may also be performed to prevent interpolation between widely separated grid points.

Once the grid points for interpolation have been identified, one embodiment of the present subject matter may employ weighted averaging to determine a final interpolated location. An exemplary weight assigned to the $i^{th}$ grid point in computing the final interpolated location may be determined by the following relationship:

$$Wi = \frac{\frac{1}{Ci}}{\sum_{i=1}^{N}\left(\frac{1}{Ci}\right)} \tag{5}$$

where $C_i$ is a metric associated with an $i^{th}$ grid point. Weighted averaging may also be utilized rather than uniform weighting to ensure that the best matching grid point (i.e., minimum cost grid point) exerts a larger influence on the final location estimate.

As discussed above, each grid point (NUG or UG) may provide one or a plurality of parameters and/or functions characterizing the grid point. Given a received set of one or more NMRs obtained at an unknown location, an accurate estimation of the unknown location may be determined using a characterization of the grid points over a geographic region. In one embodiment of the present subject matter, a distortion measure may be determined between available NMRs and grid point characteristics to assist in the estimation.

Generally, embodiments of the present subject matter may utilize any number of methods to determine a distortion measure, e.g., a mismatch distance between mobile reported measurements and a candidate grid point's stored measurement data. The associated "cost" value may also be inversely proportional to an increasing function of the probability that the mobile device is located at or in the vicinity of a grid point.

In one embodiment of the present subject matter, a distortion measure may comprise a combination of the values of each parameter in an NMR and each corresponding parameter in the grid point (NUG or UG) characteristics. The distortion measure may generally increase as the mismatch between any of the parameters increases and vice versa. For example, an exemplary cost value may be determined utilizing a Mahalanobis distance provided by the following relationship:

$$\text{COST} = \alpha(TA_{rpt} - TA_{cand})^2 + \sum_i\left[\left(\frac{RxLevDiff(i)^2}{MAXDIFF^2}\right)NCCU\right] \tag{6}$$

where α is 0 or 1 which controls whether TA differences are included in the determination (e.g., 1 for GSM and 0 for iDEN), $TA_{rpt}$ is the TA for the NMR, $TA_{cand}$ is the TA for the candidate grid point in the calibration database and/or a representative value, RxLevDiff(i) represents the difference in RxLev (received signal strength) for the $i^{th}$ neighbor cell or serving cell, I is an index to neighbor or serving cells (e.g., if only NC received signal strengths are used and there are six reporting NCs, then i=1 to 6; if in addition, a serving cell signal strength is included then i=1 to 7), NCCU represents an NC cost unit where an increasing NCCU increases the cost penalty for RxLev difference relative to the cost penalty for TA difference, and MAXDIFF is a configurable parameter that limits the cost incurred for differences in signal strengths. MAXDIFF may be set to 20 dB or another configurable value. RxLev differences exceeding MAXDIFF would not incur an additional cost penalty.

Embodiments of the present subject matter may determine RxLevDiff(i) through any number of methods including, but not limited to, the following relationships:

$$\text{RxLevDiff}(i)=(\text{RxLevServ}-\text{RxLevNeigh}(i))_{NMR}-(\text{RxLevServ}-\text{RxLevNeigh}(i))_{CND} \tag{7}$$

for i=1:6;

$$\text{RxLevDiff}(i)=(\text{RxLevNeigh}(i))_{NMR}-(\text{RxLevNeigh}(i))_{CND} \quad (8)$$

for i=1:6;

$$\text{RxLevDiff}(i)=(\text{RxLevNeigh}(l)-\text{RxLevNeigh}(i))_{NMR}-(\text{RxLevNeigh}(l)-\text{RxLevNeigh}(i))_{CND} \quad (9)$$

for i=2:6;

$$\text{RxLevDiff}(i)=(\text{AvgRxLevNeigh}-\text{RxLevNeigh}(i))_{NMR}-(\text{AvgRxLevNeigh}-\text{RxLevNeigh}(i))_{CND} \quad (10)$$

for i=1:6;

$$\text{RxLevDiff}(i)=(\text{AvgRxLev}-\text{RxLev}(i))_{NMR}-(\text{AvgRxLev}-\text{RxLev}(i))_{CND} \quad (11)$$

for i=1:7.

With reference to the above relationships, Equation (7) provides a comparison between the signal strengths of the serving cell and the $i^{th}$ NC between NMR and candidate points, Equation (8) provides a comparison between the signal strengths of the $i^{th}$ NC between NMR and candidate points, Equation (9) provides a comparison between the signal strengths of a first common NC and the $i^{th}$ NC between NMR and candidate points, Equation (10) provides a comparison between the average signal strengths of the NCs and the signal strengths of the $i^{th}$ NC between NMR and candidate points, and Equation (11) provides a comparison of the average signal strengths of the serving cells and NCs and the signal strengths of the $i^{th}$ serving cell and NC between NMR and candidate points.

In a further aspect of embodiments of the present subject matter, an estimated location may be generated for a mobile device given a received NMR and a region "R" over which a set "S" of grid points (NUGs or UGs) have been established. As described above, each grid point may include a series of parameters, components and/or functions characterizing the respective grid point. Provided a received set of one or more NMRs obtained at some unknown location, an estimation of that unknown location may be determined as a function of a characterization of the grid points over this region R.

In one embodiment of the present subject matter, an estimated location of a mobile device may be determined using any single NMR (drawn from a set or subset of NMRs) by any number of the following methods or combinations thereof. For example, one embodiment may match an ordered list of NCs, where the ordering may be in terms of any one of a number of parameters characterizing the NMR, such as, for example, NC power level, in a respective NMR to a similarly ordered list of NCs in the grid point(s) (NUG or UG) and (a) generate the estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as weight for the respective cluster), (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

In an additional embodiment, if the ordered list of NCs in the NMR (ordered with respect to the magnitude of any particular parameter characterizing the NMR) does not provide an exact match to the ordered list of NCs that may be available as a characteristic of a grid point, the method may evaluate those grid points (NUGs or UGs) including an ordered list thereof that may contain an ordered list in the NMR. Thus, the ordered list in the NMR may form a subset of the ordered list in the grid point, and the method may (a) generate an estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

In embodiments of the present subject matter where the ordered list of NCs in the NMR is not contained in the ordered list of NCs for any grid point, then the method may utilize the highest power subset of NCs in the NMR (e.g., ordered from highest to lowest power) that provides either an exact match or is contained in the ordered list of NCs in the grid point. The method may then (a) generate an estimated location as the centroid of the best cluster of matching grid points, (b) generate the estimated location as the location of the highest joint probability matching grid point, (c) generate the estimated location as the (joint probability) weighted sum of the locations of a set of matching grid points, (d) generate the estimated location as the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (e) generate the estimated location by combining locations derived from NMR subsets, or any combination thereof.

In a further embodiment of the present subject matter, the individual pdf of each NC power level or other parameter in the NMR over the set of available grid points (NUGs or UGs) may be evaluated. A joint probability may then be determined as the product of such marginal probabilities and an estimated location generated as (a) the location of the highest joint probability matching grid point, (b) the (joint probability) weighted sum of the locations of a set of matching grid points, (c) the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (d) a combination of locations derived from NMR subsets, or any combination thereof.

In one embodiment, the joint probability of the NMR NC power levels or other parameters may be evaluated over the set of available grid points. The method may then generate an estimated location as (a) the location of the highest joint probability matching grid point, (b) the (joint probability) weighted sum of the locations of a set of matching grid points, (c) the (joint probability) weighted sum of the clustered locations of a set of matching grid points, (d) a combination of locations derived from NMR subsets, or any combination thereof.

In another embodiment, a distortion measure may be determined between the grid point measured parameters (e.g., mean NC power level, TA value, RTT value, etc.) and corresponding parameters in the NMR. Exemplary distortion measures have been provided above and may be, but are not limited to, a Mahalanobis distance, etc. Any weighting in this distance over dissimilar parameters may also be optimized empirically or determined by calculation. Utilizing an exemplary distortion measure, the method may generate an estimated location as (a) the location of the grid point with a least distortion measure, (b) the weighted sum of the locations of the set of grid points (weights may also be applied as a function of the distortion measure), (c) the weighted sum of any one or multiple clustered locations of a set of grid points,

(d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

In yet another embodiment, an estimated location may be selected by matching the NC power level or other parameter ordering in the NMR to the NC power or other parameter ordering in the grid points (NUG or UG) and utilize an ordering number evaluation. An exemplary ordering number may be an indicator regarding the number of relative shifts in position occurring between the NMR and the grid point(s) NC ordered power levels or other parameters. By way of a non-limiting example, in an NMR the NC power levels may be ordered as ABCDE whereas the selected grid point may provide an ordering of BACDE. This results in an ordering number of 1 (a single shift). Multiple variations of the ordering number may be considered and determined, however, these variations may be a measure of the distortion in ordering between the NC power levels evident in the grid point as compared to the NC parameters seen in the NMR. An aggregate ordering number for a set of NMRs may then be obtained by combining the ordering numbers for each individual NMR. A final estimated location may be a grid point cluster having the smallest ordering number. In a further embodiment, the ordering number or ordering of an exemplary characteristic may also be regarded as a distortion measure such that the method may generate an estimated location as (a) the location of the grid point with a least distortion measure, (b) the weighted sum of the locations of the set of grid points (weights may also be applied as a function of the distortion measure), (c) the weighted sum of any one or multiple clustered locations of a set of grid points, (d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

With respect to any of the various methods described above, embodiments of the present subject matter may also filter parameters prior to generating an estimated location. For example, an embodiment may match the serving cell/sector of candidate grid points to the serving cell/sector of the NMR and then proceed with any of the methods previously described. A further embodiment may also filter candidate grid points using other available parameters (e.g., TA, RTT, etc.) for the NMR and then proceed with any of the methods previously described. This exemplary filtering may also be set wider than the actual parameter (TA, RTT, etc.) determined value by a configurable threshold.

Candidate grid points may also be filtered by utilizing a mobile orientation parameter (e.g., indoors, outdoors, facing North or South, titled upwards, azimuth and elevation, etc.) applied during construction of the grid points, by utilizing those grid points where the serving cell identifier and serving control channel agrees with the NMR data, by utilizing the magnitude of the serving cell forward link control channel received signal level (and applying a configurable tolerance to this parameter), by eliminating those grid points not having at least N (configurable) NC received signal levels in common with the NMR, or any combination thereof and then proceeding with any of the methods previously described.

In embodiments of the present subject matter where a set of NMRs obtained at some unknown location (or locations in close proximity to each other) may be available, the aforementioned methods may be expanded to exploit the multiplicity of information. For example, an estimated location may be generated for each NMR in a set of NMRs by any or all of the methods applicable to a single NMR as indicated above and a tightest cluster of a single NMR location may be determined. Such a determination may also utilize a metric derived while locating that NMR (e.g., joint probability, Mahalanobis distance, etc.) to weight the clusters.

In another example, a representative NMR may be generated from a set of NMRs and any or all of the methods applicable to a single NMR as indicated above may be applied thereto. The representative NMR may be generated by obtaining a representative value for each of the NCs seen in the respective set of NMRs, and similarly obtaining a representative value for each of the other parameters seen in the NMRs. In another embodiment, these representative values may be obtained as a function of the available set of values, e.g., for NC power level mean or median power may be utilized.

In a further example, transitions in any of the parameters within the set of NMRs may be observed. Transitions may be utilized in reducing the applicable region for an estimated location. As many parameters represent a range of location possibilities, when a parameter changes, it may be inferred that the region of interest is at a boundary of the ranges represented by the parameter prior to and after the change. Therefore, any one of these boundaries determined for any parameter change within the applicable set may reduce the candidate region for the mobile device location. Exemplary parameter changes may be, but are not limited to, changes in signal power levels with respect to a particular NC, rate or pattern of dropping in and out of a particular NC signal, changes in serving cell or sector, changes in TA, RTT or equivalent parameter, and combinations thereof.

Additional embodiments may determine a distortion measure between the grid point characteristics or measured parameters and corresponding parameters of all NMRs taken collectively without reduction to representative values. Any weighting in this measure over dissimilar parameters may be optimized empirically. Utilizing a distortion measure, exemplary methods may generate an estimated location as (a) the location of the grid point having the least distortion measure, (b) the weighted sum of the locations of a set of grid points (any weights applied may also be a function of the distortion measure), (c) the weighted sum of clustered locations of a set of grid points, (d) as a combination of locations derived from NMR subsets (where the measure set M is now the distortion measure).

Further embodiments may match a variety of parameters and functions generated and stored describing a grid point (i.e., the grid point characteristics) with similar parameters and functions determined for the set of NMRs by utilizing a distortion measure to evaluate the similarity therebetween. Exemplary parameters and functions may be, but are not limited to, the following: (a) an ordered list of neighboring cells; (b) functions defined on the absolute neighboring cell power levels (e.g., mean, median, $k^{th}$ moment, cluster-mean, etc.); (c) functions defined on the relative neighboring cell power differences (e.g., mean, median, $k^{th}$ moment, cluster-mean, etc.); (d) serving cell/sector; (e) timing advance parameter (or equivalent); (f) individual pdf (probability density function or probability distribution function) of each neighboring cell power level; (g) joint pdf of neighboring cell power levels; (h) mean and variance of neighboring cell power levels; (i) mobile device orientation (e.g., indoors, outdoors, direction mobile device is facing (e.g., North, South, etc.), tilted upwards, azimuth, elevation, etc.); (j) a compact and/or efficient representation that enables retrieval of the calibration data NMR vectors assigned to this grid point; (k) the network state as indicated in the calibration data; (l) a confidence measure indicative of the reliability of the calibration data feeding this grid point; and (m) any combinations of the above. In this exemplary method, further embodiments may also construct a pdf for the set of NMRs and determine a similarity to the pdf for a grid point by a

measure applicable to pdfs such as, but not limited to, the Bhattacharya distance, Kullback-Liebler divergence or other measures for probability distributions. Having generated such measures with respect to the set of candidate grid points the method may generate an estimated location as (a) the location of the grid point with the least distortion measure, (b) the weighted sum of the locations of a set of grid points (any weights applied as a function of the distortion measure), (c) the weighted sum of clustered locations of a set of grid points, (d) a combination of locations derived from NMR subsets (where the measure set M is the distortion measure).

One aspect of the present subject matter may generate a location estimate of a mobile device through methods of intersections using any single NMR or set of NMRs. Utilizing a single NMR, an exemplary intersection method may generate an estimated location based upon an observation that the region of validity for any one of the parameters in a particular NMR may define a region where the estimated location of a mobile device should exist. By way of a non-limiting example, the power level or other parameter of a particular NC (e.g., NC**1**) in an NMR having a power level of P dBm may be evaluated. With regard to the calibration data such that for every NMR in a respective set of calibration data, the particular NC power level may be within +/−x dBm of P. As discussed above, every calibration data vector provides an associated location, and the location of each such data vector in a respective calibration data subset may form a representative region, R1, defining a region within a location space having a power constraint upon NC**1**. R1 may or may not be contiguous, and may even be empty. In the event that R1 is empty, then the value of x may be increased by a predetermined value (or iteratively increased) until a nonempty region emerges and comprises valid calibration data points satisfying (e.g., falling into the range of) the obtained NMR power or parameter requirement. This may then define a region formed of discrete points in two dimensional location space. Similar regions may be constructed for each of the NCs and for each of the parameters or functions in the NMR. It follows that a range array may thus be generated containing range that define maximum and minimum values for each parameter of the form of two aggregated vectors.

An intersection of the aforementioned regions may then be determined. If a non-empty intersection occurs, the range array may be modified to approach the actual NMR data vector. Any such modification may be attempted in each NC power level or other NMR parameter level individually. In this method, the intersection region may be reduced until the smallest (and possibly clustered) intersection occurs. An estimated location for a mobile device may then be determined as the centroid of this intersection or may be determined through an evaluation of the pdf or other exemplary statistical measure for the calibration data within the intersection or a selected region. Further, an estimated location may also be determined utilizing any one or combination of the methods described above with reference to the generation of a location estimate utilizing any single NMR or set of NMRs. If, however, the intersection is empty, the range array may be modified to be wider than the actual NMR vector until a feasible solution can be found. If no solution is found with the respective range array at a higher threshold, a subset of the NCs in the NMR may be evaluated (e.g., by dropping the lowest power NC in the NMR, etc.) and the entire process described above may then be employed.

A distortion measure may also be determined along with a respective range array that generates a finite intersection region. The applicable distortion measure may be determined as, but not limited to, the largest width of any NMR NC power level or parameter level in the range array, a weighted combination of the individual widths of the NMR NC power or parameter levels in the range array, the area of the final intersection region, or any combination thereof. This distortion measure can then be an indicator of the quality or expected accuracy of the eventual location estimate.

Additionally, any subsets of the NMR(s) may be examined for intersection regions. If multiple disjoint regions occur with different NMR subsets, these disjointed regions may be regarded as a set of grid points (NUGs or UGs) and evaluated for an estimated location employing any one or combination of the methods described above with reference to the generation of a location estimate utilizing a single NMR or set of NMRs. By way of a non-limiting example, a pdf may be generated for each disjointed region, and then the techniques of location estimation described above utilizing any single NMR or set of NMRs may be employed to determine which of the regions may be the best location estimate.

Utilizing a set of NMRs, an exemplary intersection method may generate an estimated location for each NMR in the set of NMRs by any or all of the methods applicable to a single NMR as discussed in the previous paragraphs and (a) determine the tightest cluster of such single NMR locations (optionally using a metric derived while locating that NMR to weight the clusters such as a distortion measure (e.g., joint probability, Mahalanobis distance, cluster radius, etc.)), (b) if multiple disjoint regions occur for one or more NMRs, use the methods described above with reference to the generation of a location estimate utilizing any single NMR or set of NMRs to determine the most likely estimate for the location estimate, and/or (c) if multiple disjoint regions occur for some NMRs but not for others, utilizing regions having an appropriate weighting and/or utilizing a distortion measure and any additional weighting that may allocate a greater likelihood to those NMRs generating a non-disjoint region.

Utilizing a set of NMRs, an exemplary intersection method may also generate a representative NMR from the set of NMRs and apply the methods described above with regard to a single NMR to the representative NMR. The representative NMR may be generated by determining a representative value for each of the NCs available in the set of NMRs and determining a representative value for each of the other parameters available in the respective NMRs. Exemplary representative values may be obtained as a function of the available set of values (e.g., for NC power, mean or median). In the alternative, this exemplary method may also consider a set of NC power or parameter levels (applicable to each NMR NC level) when viewed over the set of NMRs and select that NC level requiring the narrowest range to provide a valid region. This power or parameter level may be the applicable level in the representative NMR. It should be noted that embodiments of the present subject matter employing this exemplary method may produce results different from the aforementioned grid point approach as calibration data too few in number to effectively emerge in a pdf of the grid point(s) to which the data are applied may, however, emerge in this exemplary method.

It is also another aspect of embodiments of the present subject matter to generate a location estimate for a mobile device utilizing multiple constructions of characterizing information from grid points (NUGs or UGs) over the same region. By way of a non-limiting example, an exemplary method may utilize multiple sets of grid points constructed on the same calibration data (or over several such sests of calibration data) and select a set of grid points such that, when evaluated over the methods described above regarding single NMRs or sets of NMRs, representative NMRs, etc., provides

the best criteria of fit. Exemplary criteria may be, but are not limited to total probability, cluster radius, Euclidean norm, Mahalanobis distance or other exemplary parameters that are an indicator of a "goodness" of fit. The estimated location within the grid point construction providing the best criteria of fit may be determined as the final location estimate for a respective mobile device.

In a further embodiment of the present subject matter, clustering of data vectors may also occur in another dimension of construction space (rather than occurring purely in the location space). Therefore, if a particular location exists in the best cluster over multiple grid point constructions, that location may be determined as the correct location for the estimate. The estimated location may then be obtained by applying the methods described above regarding single NMRs or sets of NMRs, representative NMRs, etc. within selected grid point set (NUG or UG) or over all grid point sets. It follows that each construction method may also be visualized as a layer in three dimensional space having a separate set of candidate locations or clusters (associated weights may also be applied thereupon). Exemplary weights may be, but are not limited to, distortion measures, probabilities, etc. In a further embodiment of the present subject matter, a vertical combination of candidate locations across the various constructions forming the third dimension may also be employed; thus, clustering in this instance may be a process that, when viewed in each location space (which is two dimensional) and in the vertical dimension, examines each or combinations of different constructions. An acceptable location estimate may generally be expected to cluster well in both location space and construction space, and the tightness of this cluster may then be employed as an additional confidence measure upon the respective location estimate and utilized in the methods described above.

FIG. **29** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter. With reference to FIG. **29**, at block **2910**, a plurality of calibration or grid points may be provided in a geographic region. At block **2920**, a plurality of NMRs may be provided for a mobile device in the geographic region. Ones of the plurality of grid points may be compared to one or more parameters of ones of the plurality of NMRs in block **2930**. In another embodiment of the present subject matter, the comparison may further comprise generating a distortion measure that is a function of a combination of parameters of ones of the plurality of network measurement reports and corresponding parameters of ones of the plurality of grid points. An exemplary distortion measure may be, but is not limited to, a Mahalanobis distance, a comparison of received signal strengths of a serving cell and a neighboring cell between ones of the plurality of NMRs and grid points, a comparison of received signal strengths of a neighboring cell between ones of the plurality of NMRs and grid points, a comparison of received signal strengths of a first common neighboring cell and another neighboring cell between ones of the plurality of NMRs and grid points, a comparison of average received signal strengths of reporting neighboring cells and received signal strengths of a neighboring cell between ones of the plurality of NMRs and grid points, a comparison of average received signal strengths of serving and reporting neighbor cells received signal strengths of a selected neighbor or serving cell between ones of the plurality of NMRs and grid points, and any combination thereof. A first location estimate of the mobile device may be generated for each of the ones of the plurality of NMRs in block **2940**, and in block **2950**, a second location estimate of the mobile device may be determined as a function of at least one of the generated first location estimates.

FIG. **30** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates. With reference to FIG. **30**, blocks **3010**, **3020**, **3030**, **3040** and **3050** are similar to blocks **2910**, **2920**, **2930**, **2940** and **2950**, respectively. At block **3060**, the method may further determine a Mahalanobis distance from each first location estimate to the second location estimate and at block **3070**, determine a distance threshold from a median of the determined Mahalanobis distances multiplied by a predetermined factor. At block **3080**, a third location estimate may then be determined by averaging two or more of the first location estimates. In such a determination the first location estimates having a Mahalanobis distance to the second location estimate greater than a predetermined distance threshold may be omitted from the third location estimate determination.

FIG. **31** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter. With reference to FIG. **31**, blocks **3110**, **3120**, **3130**, **3140** and **3150** are similar to blocks **2910**, **2920**, **2930**, **2940** and **2950**, respectively. At block **3151**, the determination of a second location estimate may further comprise averaging two or more first location estimates, or at block **3152**, the determination of a second location estimate may further comprise employing a weighted averaging of ones of the first location estimates. At block **3153**, the determination of a second location estimate may further comprise weighting a first location estimate by an inverse of a distance metric, or at block **3154**, the determination of a second location estimate may further comprise normalizing a first location estimate by a sum of an inverse of a distance metric. Further, at block **3155**, the determination of a second location estimate may further comprise weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device.

FIG. **32** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including omitting a first location estimate. With reference to FIG. **32**, blocks **3210**, **3220**, **3230**, **3240** and **3250** are similar to blocks **2910**, **2920**, **2930**, **2940** and **2950**, respectively. At block **3260**, the method may further omit a first location estimate having an error greater than a predetermined threshold.

FIG. **33** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including interpolating between grid points. With reference to FIG. **33**, blocks **3310**, **3320**, **3330**, **3340** and **3350** are similar to blocks **2910**, **2920**, **2930**, **2940** and **2950**, respectively. At block **3360**, the method may further interpolate between ones of the plurality of grid points when more than one grid point corresponds to a parameter of the plurality of NMRs.

FIG. **34** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including interpolating between grid points and/or assigning weights to selected grid points. With reference to FIG. **34**, blocks **3410**, **3420**, **3430**, **3440**, **3450** and **3460** are similar to blocks **3310**, **3320**, **3330**, **3340**, **3350** and **3360**, respectively. At block **3461**, the interpolation may be a function of the relationship provided in Equation (3) above. With reference to Equation (3), a grid point having a $C\_Ratio_i$ less than a predetermined threshold may be a candidate grid point for the interpolation in one embodiment and/or a grid point

having a distance from the best corresponding grid point less than a predetermined threshold may be a candidate grid point for the interpolation. At block **3462**, the interpolation may also be a function of the relationship provided in Equation (4) above. At block **3470**, the method may further assign weights to an $i^{th}$ grid point as a function of the relationship provided in Equation (5) above.

FIG. **35** is a flow chart for a method for locating a mobile device according to another embodiment of the present subject matter including providing a default location. With reference to FIG. **35**, blocks **3510**, **3520**, **3530**, **3540**, and **3550** are similar to blocks **2910**, **2920**, **2930**, **2940** and **2950**, respectively. At block **3560**, the method may further comprise providing a default location for the second location estimate if a second location estimate cannot be determined as a function of at least one of the generated first location estimates. In one embodiment at block **3561**, the default location may be a predetermined distance from a serving cell serving the mobile device at a heading along a serving sector azimuth. In another embodiment at block **3562**, the default location may be a function of timing advance or round trip time and/or may be an approximate range estimate from a serving cell serving the mobile device. In an additional embodiment in block **3563**, the default location may be a region determined as a function of a TDOA measurement and/or where the region is the intersection of a hyperbola defined by said TDOA with a timing advance region applicable to a serving cell serving the mobile device. In yet a further embodiment in block **3564**, the default location may be determined as a function of a priori knowledge of sector coverage density.

FIG. **36** is a flow chart for a method of improving a location estimate of a mobile device. With reference to FIG. **36**, at block **3610**, a plurality of grid points in a geographic region may be provided and at block **3620**, a set of NMRs for a mobile device in the geographic region may be provided. The set of NMRs may or may not include one or more subsets of NMRs. At block **3630**, ones of the plurality of grid points may be compared to at least one parameter of a subset of the NMRs, and at block **3640**, a first location estimate of the mobile device may be generated for each subset of NMRs. A second location estimate of the mobile device may be determined as a function of at least one of the generated first location estimates at block **3650**, and at block **3660**, an attribute of the second location estimate may be indicated as a function of a parameter of a subset of the NMRs. In additional embodiments, the attribute may be determined as a function of any one or combination of a fraction of first location estimates corresponding with the second location estimate and a fraction of total first location estimates that lie within a predetermined distance of the second location estimate.

FIG. **37** is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter. With reference to FIG. **37**, blocks **3710**, **3720**, **3730**, **3740**, **3750** and **3760** are similar to blocks **3610**, **3620**, **3630**, **3640**, **3650** and **3660**, respectively. At block **3751**, the determination of a second location estimate may further comprise clustering the set of NMRs without reference to parameters in any of the subsets of NMRs. At block **3752**, the second location estimate may be determined as the centroid of a region containing the tightest cluster of NMRs in the set of NMRs. The cluster may or may not possess an aggregate measure higher than a predetermined threshold. At block **3753**, the second location estimate may be determined as the centroid of ones of the plurality of grid points occurring most often in the set of NMRs. At block **3754**, the determination of a second location estimate may further comprise clustering a subset of NMRs as a function of power of neighboring cells. At block **3755**, the determination of a second location estimate may further comprise clustering a subset of NMRs as a function of power of neighboring cells and another parameter in the subset. At block **3756**, the determination of a second location estimate may further comprise averaging two or more first location estimates. At block **3757**, the determination of a second location estimate may also further comprise employing a weighted averaging of ones of the first location estimates. In another embodiment, at block **3758**, the determination of a second location estimate may further comprise weighting a first location estimate by an inverse of a distance metric. At block **3759**, the determination of a second location estimate may also comprise normalizing a first location estimate by a sum of an inverse of a distance metric, and at block **3761**, the determination of a second location estimate may further comprise weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device. In another embodiment at block **3762**, the determination of a second location estimate may further comprise weighting a first location estimate as a function of the indicated attribute. Exemplary weighting may be, but is not limited to, a Mahalanobis distance, a probability density function.

FIG. **38** is a flow chart for a method of improving a location estimate of a mobile device according to another embodiment of the present subject matter including omitting a first location estimate. With reference to FIG. **38**, blocks **3810**, **3820**, **3830**, **3840**, **3850** and **3860** are similar to blocks **3610**, **3620**, **3630**, **3640**, **3650** and **3660**, respectively. At block **3870**, the method may further omit a first location estimate having an error greater than a predetermined threshold.

FIG. **39** is a flow chart for a method for locating a mobile device according to one embodiment of the present subject matter including identifying and omitting outlier first location estimates. With reference to FIG. **39**, blocks **3910**, **3920**, **3930**, **3940**, **3950** and **3960** are similar to blocks **3610**, **3620**, **3630**, **3640**, **3650** and **3660** respectively. At block **3970**, the method may further determine a Mahalanobis distance from each first location estimate to the second location estimate and at block **3980**, determine a distance threshold from a median of the determined Mahalanobis distances multiplied by a predetermined factor. At block **3990**, a third location estimate may then be determined by averaging two or more of the first location estimates. In such a determination the first location estimates having a Mahalanobis distance to the second location estimate greater than a predetermined distance threshold may be omitted from the third location estimate determination.

FIG. **40** is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter. With reference to FIG. **40**, blocks **4010**, **4020**, **4030**, **4040**, **4050** and **4060** are similar to blocks **3610**, **3620**, **3630**, **3640**, **3650** and **3660**, respectively. At block **4061**, the indication of an attribute of the second location estimate may further comprise determining an error estimate as an average of distances from each first location estimate to the second location estimate. In one embodiment at block **4062**, the error estimate may be determined as a function of the relationship provided in Equation (1) above. In a further embodiment at block **4063**, the error estimate may be determined as a function of the relationship provided in Equation (2) above. With reference to Equation (2), exemplary weighting factors may be, but are not limited to probabilities determined during the first location estimate generation, probabilities determined during the second location estimate determination, distortion function values deter-

mined during the first location estimate generation, distortion function values determined during the second location estimate determination, and combinations thereof. In yet another embodiment in block **4064**, the error estimate may be determined as a function of subset NMR cluster separation between a highest aggregate weighted cluster.

FIG. **41** is a flow chart for a method of improving a location estimate of a mobile device according to a further embodiment of the present subject matter including providing a default location. With reference to FIG. **41**, blocks **4110**, **4120**, **4130**, **4140**, **4150** and **4160** are similar to blocks **3610**, **3620**, **3630**, **3640**, **3650** and **3660**, respectively. At block **4170**, a default location may be provided for the second location estimate if the attribute is less than a predetermined threshold. In one embodiment at block **4171**, the default location may be a predetermined distance from a serving cell serving the mobile device at a heading along a serving sector azimuth. In another embodiment at block **4172**, the default location may be a function of timing advance or round trip time and/or may be an approximate range estimate from a serving cell serving the mobile device. In an additional embodiment in block **4173**, the default location may be a region determined as a function of a TDOA measurement and/or where the region is the intersection of a hyperbola defined by said TDOA with a timing advance region applicable to a serving cell serving the mobile device. In yet a further embodiment in block **4174**, the default location may be determined as a function of a priori knowledge of sector coverage density.

FIG. **42** is a flow chart for a method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **42**, at block **4210**, a plurality of grid points may be provided in a geographic region where each of the grid points may include at least one characterizing parameter or characterizing function, and where each of the grid points is located on a grid defined over the geographic region. At block **4220**, a plurality of NMRs may be provided for a mobile device in the geographic region, and at block **4230**, an estimated location may be determined for the mobile device from one NMR as a function of the at least one parameter. Of course, one or more of the grid points may be randomly located within the geographic region, and one or more of the grid points may be located on a predetermined fixed uniform grid defined over the geographic region.

FIG. **43** is a flow chart for a method of locating a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to FIG. **43**, blocks **4310**, **4320** and **4330** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4340**, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to an ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level or NC measurement quality. At block **4350**, an estimated location may be generated for the mobile device which may comprise a centroid of a cluster of best matching grid points in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block **4360**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points in the grid to the serving cell (provided such a characterization is available for the respective grid points) or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **44** is a flow chart for a method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to FIG. **44**, blocks **4410**, **4420** and **4430** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4440**, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to a similarly ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level. At block **4450**, if no exact match exists between the ordered list of neighboring cells of the one NMR and any grid point on the grid, then a largest subset of the ordered list of neighboring cells in the grid points may be formed that matches the NMR. At block **4460**, an estimated location may be generated for the mobile device which may comprise a centroid of a cluster of thus matched grid points, clustered by location, in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block **4470**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for those grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **45** is a flow chart for a method of locating a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **45**, blocks **4510**, **4520** and **4530** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4540**, the determination of an estimated location for the mobile device may further include comparing an ordered list of cells neighboring a cell serving the mobile device in the one NMR to an ordered list of neighboring cells in the grid. The ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level. At block **4550**, if the ordered list of neighboring cells of the one NMR is not contained in the ordered list of neighboring cells for the grid, then a largest

ordered subset of neighboring cells in the one NMR may be utilized having either an exact match or is contained in the ordered list of neighboring cells in the grid. At block **4560**, an estimated location of the mobile device may be generated that may comprise a centroid of a cluster, clustered by location, of thus matched grid points in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations determined from subsets of the plurality of NMRs. At block **4570**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for those grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **46** is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to FIG. **46**, blocks **4610**, **4620** and **4630** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4640**, the determination of an estimated location for the mobile device may further include evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the one NMR over each grid point of a set of available grid points in the grid. At block **4650**, a joint probability may then be determined as a function of the individual probability density functions, and at block **4660**, an estimated location of the mobile device may be generated that may comprise a centroid of a cluster of highest probability grid points, clustered by location, in the grid, a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations determined from subsets of the plurality of NMRs. At block **4670**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **47** is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to FIG. **47**, blocks **4710**, **4720** and **4730** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4740**, the determination of an estimated location for the mobile device may further include directly evaluating a joint probability (i.e., as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the one NMR over a set of available grid points in the grid. At block **4750**, an estimated location of the mobile device may be generated that may comprise a highest joint probability matching grid point in the grid, a weighted sum of the locations of a set of matching grid points in the grid (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of locations determined from subsets of the plurality of NMRs. At block **4760**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **48** is a flow chart for a method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to FIG. **48**, blocks **4810**, **4820** and **4830** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4840**, the determination of an estimated location for the mobile device may further include determining a distortion measure between a characteristic function or parameter of a grid point and a corresponding function or parameter obtained for the one NMR. At block **4850**, an estimated location of the mobile device may be generated that may comprise a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the grid (where the weighting applied to each of the matching grid points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid, as a function of locations determined from subsets of the plurality of NMRs, or any combination thereof. At block **4860**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof. In an additional embodiment, the distortion measure may be, but is not limited to, a Mahalanobis distance.

FIG. **49** is a flow chart for a method of locating a mobile device in a geographic region according to yet another

embodiment of the present subject matter. With reference to FIG. **49**, blocks **4910**, **4920** and **4930** are similar to blocks **4210**, **4220** and **4230**, respectively. At block **4940**, the determination of an estimated location for the mobile device may further include matching cell power ordering of cells neighboring a cell serving the mobile device in the one NMR to neighboring cell power ordering in each of the grid points in the grid. At block **4950**, an estimated location may then be selected as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the one NMR and grid point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith. At block **4960**, a further embodiment may also filter available grid points as a function of any one or combination of selected characteristics, such as, but not limited to, a matching of serving cell or sector for grid points (provided such a characterization is available for the respective grid points) in the grid to the serving cell or sector of the one NMR, a TA parameter from the one NMR, a RTT parameter from the one NMR, a mobile device orientation parameter, a serving cell identifier, a serving control channel, a magnitude of a serving cell forward link control channel received signal level, a predetermined number of cell received signal levels common to the one NMR, or any combination thereof.

FIG. **50** is a flow chart for another method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **50**, at block **5010**, a plurality of grid points may be provided in a geographic region where each of the grid points may include at least one characterizing parameter and each of the grid points may be located on a grid defined over the geographic region. At block **5020**, a plurality of NMRs may be provided for a mobile device in the geographic region, and at block **5030**, an estimated location may be determined for the mobile device from a set of said plurality of network measurement reports as a function of the parameter. Of course, one or more of the grid points may be randomly located within the geographic region, and one or more of the grid points may be located on a predetermined fixed uniform grid defined over the geographic region.

FIG. **51** is a flow chart for another method of locating a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **51**, blocks **5110**, **5120** and **5130** are similar to blocks **5010**, **5020** and **5030**, respectively. At block **5140**, the determination of an estimated location for the mobile device may also include determining a cluster for each NMR characteristic or parameter, clustered by location, in the set of NMRs. The clustering may further be weighted by an exemplary metric that may be, but is not limited to, a Mahalanobis distance, joint probability, probability density function, and any combination thereof.

FIG. **52** is a flow chart for another method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to FIG. **52**, blocks **5210**, **5220** and **5230** are similar to blocks **5010**, **5020** and **5030**, respectively. At block **5240**, the determination of an estimated location for the mobile device may include determining a representative value for each parameter occurring in the set of NMRs. At block **5250**, a cluster for each representative value may also be weighted by an exemplary metric (e.g., a Mahalanobis distance, joint probability, probability density function, etc.) to weight the cluster. An exemplary representative value may be, but is not limited to, serving cell power level, neighboring cell power level, timing advance, round trip time, or any combination thereof. Further, the representative value may be determined as a function of a mean or median of a set of parameter values obtained over the set of NMRs.

FIG. **53** is a flow chart for another method of locating a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **53**, blocks **5310**, **5320** and **5330** are similar to blocks **5010**, **5020** and **5030**, respectively. At block **5340**, the determination of an estimated location for the mobile device may also include observing a transition in a parameter occurring in one or more of the NMRs within an applicable set of NMRs. At block **5350**, a location of the mobile device may be estimated on a boundary defined by a first range represented by the parameter before the transition and by a second range represented by the parameter after the transition. An exemplary parameter may be, but is not limited to, signal power level, signal quality, rate of dropping in/out of a neighboring cell signal, pattern of dropping in/out of a neighboring cell signal, changes in serving cell, changes in serving sector, RTT, TA, and any combinations thereof.

FIG. **54** is a flow chart for another method of locating a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to FIG. **54**, blocks **5410**, **5420** and **5430** are similar to blocks **5010**, **5020** and **5030**, respectively. At block **5440**, the determination of an estimated location for the mobile device may also determine a distortion measure between a parameter or function of ones of the grid points and a corresponding parameter or function in each NMR in the set. At block **5450**, an estimated location of the mobile device may be generated where the estimated location may be, but is not limited to, a location of the grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the grid (where the weighting applied to each grid point may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from subsets of the set of NMRs by the preceding methods, and any combination thereof. An exemplary distortion measure may be, but is not limited to, a Mahalanobis distance.

FIG. **55** is a flow chart for another method of locating a mobile device in a geographic region according to yet another embodiment of the present subject matter. With reference to FIG. **55**, blocks **5510**, **5520** and **5530** are similar to blocks **5010**, **5020** and **5030**, respectively. At block **5540**, the determination of an estimated location for the mobile device may determine a representative value for each cell neighboring a serving cell serving the mobile device in the set of NMRs. More generally, for each parameter type held in common by an non-empty subset of the NMRs, a representative value may be generated. At block **5550**, a distortion measure for each representative value may be determined as a function of a comparison between a parameter of ones of the grid points and a corresponding parameter for each representative value. At block **5560**, an estimated location of the mobile device may be generated where the estimated location may comprise a location of the grid point having the smallest overall distortion measure (computed over all parameters of the set of NMRs), a weighted sum of the locations of a set of matching grid points in the grid (where the weighting may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the grid, as a function

of estimated locations determined from subsets of the set of NMRs by the preceding methods, or any combination thereof.

FIG. **56** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **56**, at block **5610**, calibration data may be provided for each of one or more calibration points in a geographic region where the calibration data may include a collection of NMRs having associated known locations. Of course, each of the NMRs provide at least one characterizing parameter. The calibration data may take the form of a collection of NMRs having associated locations as discussed above. Exemplary NMRs in the calibration data may be defined as an (n×1) vector with n parameters. Exemplary parameters may be, but are not limited to, observed power levels for adjacent neighbor cell control channels, TAs, RTTs, etc., each of which are a set of observed or collected information obtained at a particular location. A particular value of n, i.e., the size of each NMR vector, may be variable (e.g., n may range from at least one to fifteen or higher within a respective calibration data set). At block **5610**, a candidate NMR may also be received from a mobile device at an unknown location. Thus, the geographical location from which the candidate NMR was generated should be estimated. At block **5620**, a first region may be defined within the calibration data as a function of a first characterizing parameter of the candidate NMR and a predetermined range of the first parameter. At block **5630**, a second region may be defined within the calibration data as a function of a second characterizing parameter of the candidate NMR and a predetermined range of the second parameter.

By way of a non-limiting example, if the candidate NMR is a (4×1) vector including components that represent the power levels observed for some cells A, B and H and a fourth component that represents a TA value with respect to cell D, the candidate NMR vector may be provided by the following relationship:

$$\text{NMR\_c} = \begin{bmatrix} Pa \\ Pb \\ Ph \\ TAd \end{bmatrix} \tag{12}$$

With reference to Equation 12, if the first characterizing parameter of the candidate NMR considered is the power level observed for cell A, then the calibration data may be examined for each NMR (or data vector) having a power level observed for cell A that may be within a predetermined range about the value Pa. A set of such exemplary NMRs (or data vectors) within the calibration data satisfying this condition defines a region R1 in a two dimensional location space where a location is desired. As each such piece of calibration data (e.g., each NMR in the calibration data) that fits (i.e., fits the range constraint upon the first parameter) has an associated location, it follows that a collection of such pieces or data vectors of calibration data may define a region. Further, assuming the second characterizing parameter considered is the power level observed for cell H, the same technique may also be applied to generate a second region R2. These regions may then represent areas in a location space that are potential or candidate solution regions for the location of the unknown (e.g., candidate) NMR. The intersection of these two (or more) regions defines a region satisfying the two characterizing parameters considered within a respective range for each. Of course, a multitude of parameters may be considered and a multitude of regions defined, thus, the simplistic example provided above should not limit the scope of the claims appended herewith.

The steps represented by blocks **5620** and **5630** may be repeated for each characterizing parameter in the candidate NMR and calibration data at block **5640**. An intersection of the defined regions may be determined at block **5650** and at block **5660**, the location of a mobile device in the geographic region may be estimated as a function of the intersection. It may be noted that any such intersection region may be equivalent to the geographic locations of the set of corresponding calibration points whose parameters, when suitably expanded in range define this intersection region. Alternatively, the intersection region can be equivalently treated as a subset of the original calibration points obtained by expanding the parameter ranges of the candidate NMR. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

FIG. **57** is a flow chart for another method of estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **57**, blocks **5710**, **5720**, **5730**, **5740**, **5750** and **5760** are similar to blocks **5610**, **5620**, **5630**, **5640**, **5650** and **5660**, respectively. At block **5770**, the estimation of the location of a mobile device may further comprise estimating the location of a mobile device as a function of a statistical measure for calibration data of select ones of the calibration points (these calibration points may correspond to the final intersection). An exemplary statistical measure may be, but is not limited to, a probability density function. At block **5780**, in one embodiment of the present subject matter the estimated location of a mobile device may be the centroid of the intersection.

FIG. **58** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to one embodiment of the present subject matter. With reference to FIG. **58**, blocks **5810**, **5820**, **5830**, **5840**, **5850** and **5860** are similar to blocks **5610**, **5620**, **5630**, **5640**, **5650** and **5660**, respectively. At block **5870**, in one embodiment, the intersection may be determined as a function of a distortion measure.

FIG. **59** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **59**, blocks **5910**, **5920**, **5930**, **5940**, **5950** and **5960** are similar to blocks **5610**, **5620**, **5630**, **5640**, **5650** and **5660**, respectively. At block **5961**, in one embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to an ordered list of neighboring cells in the intersection region or intersection (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level or NC measurement quality), and (b) generating an estimated location of the

mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of best matching calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

In another embodiment of the present subject matter, at block **5962**, the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to a similarly ordered list of neighboring cells in the intersection region (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level), (b) if no exact match exists between the ordered list of neighboring cells of the at least one NMR and any calibration point in the intersection region then a subset of the largest ordered list of neighboring cells may be formed in the intersection region, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matched calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

At block **5963**, the estimation of the location of a mobile device may comprise in a further embodiment of the present subject matter (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the at least one NMR to an ordered list of neighboring cells in the intersection region (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level), (b) if the ordered list of neighboring cells of the at least one NMR is not contained in the ordered list of neighboring cells for the intersection region, then a largest ordered subset of neighboring cells in the at least one NMR may be utilized having either an exact match or is contained in the ordered list of neighboring cells in the intersection region, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matched calibration points in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

At block **5964**, in another embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) evaluating a pdf for each parameter of a cell neighboring a cell serving the mobile device in the at least one NMR over each calibration point in a set of available calibration points in the intersection region, (b) determining a joint probability as a function of the pdfs, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of highest probability calibration points, clustered by location, in the intersection region, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

At block **5965**, the estimation of the location of a mobile device may comprise in one embodiment of the present subject matter (a) directly evaluating a joint probability (i.e., as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the at least one NMR over a set of available calibration points in the intersection region, and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching calibration point in the intersection region, a weighted sum of the locations of a set of matching calibration points in the intersection region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of estimated locations determined from a subset of the at least one NMR, or any combination thereof.

At block **5966**, the estimation of the location of a mobile device may comprise in an additional embodiment of the present subject matter (a) determining a distortion measure between a characteristic function or parameter of a calibration point and a corresponding function or parameter in the at least one NMR and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a calibration point having the smallest distortion measure, a weighted sum of the locations of a set of matching calibration points in the intersection region (where the weighting applied to each of the matching calibration points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching calibration points in the intersection region, as a function of locations determined from a subset of the at least one NMR, or any combination thereof. Exemplary distortion measures are described above and may be, but are not limited to, a Mahalanobis distance, etc.

In one embodiment of the present subject matter, at block **5967** the estimation of the location of a mobile device may

comprise (a) matching cell power ordering of cells neighboring a cell serving the mobile device in the at least one NMR to neighboring cell power ordering of calibration points in each of the calibration points in the intersection region and (b) selecting an estimated location as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the at least one NMR and calibration point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith.

FIG. **60** is a flow chart for a method of estimating the location of a mobile device in a geographic region. At block **6010**, calibration data may be provided for a plurality of calibration points in the geographic region. The calibration data may include at least one characterizing parameter and for each of select ones of the calibration points the calibration data may also include plural data vectors. Of course, the calibration data may include a collection of NMRs having associated known locations, each of the NMRs providing at least one characterizing parameter. The calibration data may take the form of a collection of NMRs having associated locations as discussed above. Exemplary NMRs in the calibration data may be defined as an (n×1) vector with n parameters. Exemplary parameters may be, but are not limited to, observed power levels for adjacent neighbor cell control channels, TAs, RTTs, etc., each of which are a set of observed or collected information obtained at a particular location. A particular value of n, i.e., the size of each NMR vector, may also be variable (e.g., n may range from at least one to fifteen or higher within a respective calibration data set). A candidate set of NMRs may also be received from a mobile device at an unknown location. Thus, the geographical location from which the candidate set was generated should be estimated.

At block **6020**, a first region within the calibration data may be defined as a function of a first characterizing parameter of the set of NMRs and a predetermined range of the first parameter. At block **6030**, a second region within the calibration data may be defined as a function of another characterizing parameter of the set of NMRs and a predetermined range of another parameter. By way of a non-limiting example, if the first characterizing parameter of the candidate set considered is the power level observed for a first cell, A, then the calibration data may be examined for each NMR in the set (or data vector) having a power level observed for cell A that may be within a predetermined range about the value Pa. Exemplary NMRs (or data vectors) within the calibration data satisfying this condition may defines a region in a two dimensional location space where a location is desired. As each such piece of calibration data that fits the range constraint upon the first parameter has an associated location, it follows that a collection of such pieces or data vectors of calibration data may define a region. Further, assuming the second characterizing parameter considered is the power level observed for cell B, the same technique may also be applied to generate a second region. These regions may then represent areas in a location space that are potential or candidate solution regions for the location of the unknown set of NMRs. The intersection of these two (or more) regions defines a region satisfying the two characterizing parameters considered within a respective range for each. Of course, a multitude of parameters may be considered and a multitude of regions defined, and an intersection of this multitude of regions may also be obtained. Thus, the simplistic example provided above should not limit the scope of the claims appended herewith.

The steps represented by blocks **6020** and **6030** may be repeated for each characterizing parameter in the set of calibration data at block **6040**. At block **6050**, a clustering of the plural data vectors, whether directly in the regions obtained or for those data vectors than are contained in the intersection, may be determined. In another embodiment of the present subject matter, the clustering may be determined as a function of a metric, such as, but not limited to, joint probability, Mahalanobis distance, cluster radius, etc. It may be noted that clustering may also be generally viewed as a process generating an intersection region. At block **6060**, a location of a mobile device in the intersection region may be estimated as a function of the clustering. In one embodiment, any number or combination of the calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or may be randomly located within the geographic region. Further, any of the calibration data may comprise information from a network measurement report. The calibration data for one of the calibration points may be obtained from one or more mobile devices located in close proximity to the one calibration point in another embodiment, and/or the calibration data for one of the calibration points may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region.

FIG. **61** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to FIG. **61**, at block **6110**, calibration data for each of one or more calibration points in a geographic region may be provided where the calibration data includes at least one characterizing parameter. Further, a set of network measurement reports may be received from a mobile device at an unknown location where at least one of the network measurement reports in the set also includes at least one characterizing parameter. At block **6120**, a representative value may be determined for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set. In one embodiment of the present subject matter, the representative value may be obtained as a function of an available set of representative values, may be determined as a function of a mean or median of an available set of representative values, or may be selected as a function of a predetermined range. At block **6130**, one or more representative network measurement reports may be determined as a function of the representative value, and at block **6140** the location of a mobile device may be estimated in the geographic region as a function of the one or more representative network measurement reports. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter, for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

FIG. **62** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **62**, blocks **6210**, **6220**, **6230** and **6240** are

similar to blocks **6110**, **6120**, **6130** and **6140**, respectively. In one embodiment the method may further define a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value at block **6250** and at block **6260** define a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of the second value. The steps represented by blocks **6250** and **6260** may be repeated for each characterizing parameter in the one or more representative NMRs at block **6270**. At block **6280**, an intersection of each defined region may be determined and at block **6290**, the location of a mobile device in the geographic region may be estimated as a function of the intersection. At block **6291**, in one embodiment of the present subject matter the location of a mobile device may be estimated as the centroid of the intersection, or at block **6292**, the location of the mobile device may be estimated as a function of a statistical measure for calibration data of select ones of the calibration points. An exemplary statistical measure may be, but is not limited to, a probability density function.

FIG. **63** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to FIG. **63**, blocks **6310**, **6320**, **6330**, **6340**, **6350**, **6360**, **6370**, **6380** and **6390** are similar to blocks **6210**, **6220**, **6230**, **6240**, **6250**, **6260**, **6270**, **6280** and **6290**, respectively. At block **6381**, in one embodiment of the present subject matter an intersection of each defined region may be determined as a function of a distortion measure.

FIG. **64** is a flow chart for a method of estimating the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **64**, blocks **6410**, **6420**, **6430**, **6440**, **6450**, **6460**, **6470**, **6480** and **6490** are similar to blocks **6210**, **6220**, **6230**, **6240**, **6250**, **6260**, **6270**, **6280** and **6290** respectively. At block **6491**, in one embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration point of the intersection where the ordering may be a function of any parameter of the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level or NC measurement quality); and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection; a highest joint probability matching calibration point in the intersection; a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.); a weighted sum of clustered locations of a set of matching calibration points in the intersection (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

In another embodiment of the present subject matter, at block **6492**, the estimation of the location of a mobile device may comprise (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration point of the intersection where the ordering may be a function of any parameter in the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level or NC measurement quality), (b) if no exact match is made between the ordered list of neighboring cells of the one or more representative network measurement reports and any calibration point in the intersection then forming a largest subset of the ordered list of neighboring cells in the calibration points that provide a match, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

At block **6493**, the estimation of the location of a mobile device may comprise in a further embodiment of the present subject matter (a) comparing an ordered list of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to an ordered list of neighboring cells in each calibration point of the intersection where the ordering may be a function of any parameter in the one or more representative network measurement reports (the ordering may be in terms of any one of a number of parameters characterizing a respective NMR, e.g., NC power level), (b) if the ordered list of neighboring cells of the one or more representative network measurement reports is not contained in the ordered list of neighboring cells for the intersection then using a largest subset of ordered neighboring cells in the one or more representative network measurement reports having either an exact match or contained in the ordered list of neighboring cells in the intersection, and (c) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching calibration points in the intersection, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

At block **6494**, in another embodiment of the present subject matter the estimation of the location of a mobile device may comprise (a) evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the one or more representative network measurement reports over each calibration point in a set of available calibration points in the intersection, (b) determining a joint probability as a function of the individual probability density functions, and (c) generating an estimated location of the mobile device. The estimated location may be,

but is not limited to, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

At block **6495**, the estimation of the location of a mobile device may comprise in one embodiment of the present subject matter (a) directly evaluating a joint probability (i.e., as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the one or more representative network measurement reports over a set of available calibration points in the intersection, and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching calibration point in the intersection, a weighted sum of the locations of a set of matching calibration points in the intersection (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching calibration points in the intersection (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), and as a function of estimated locations determined from a subset of the one or more representative network measurement reports, or any combination thereof.

At block **6496**, the estimation of the location of a mobile device may comprise in an additional embodiment of the present subject matter (a) determining a distortion measure between a parameter or function of a calibration point contained in the intersection and a corresponding parameter or function in the one or more network measurement reports, and (b) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a calibration point having the smallest distortion measure, a weighting of the locations of a set of matching calibration points in the intersection (where the weighting applied to each of the matching calibration points may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching calibration points in the intersection, and as a function of estimated locations determined from a subset of the one or more representative network measurement reports. Exemplary distortion measures are described above and may be but, but are not limited to, a Mahalanobis distance, etc.

In one embodiment of the present subject matter, at block **6497** the estimation of the location of a mobile device may comprise (a) matching cell power ordering of cells neighboring a cell serving the mobile device in the one or more representative network measurement reports to neighboring cell power ordering of calibration points in each of the calibration points in the intersection region, and (b) selecting an estimated location as a function of a quality of the matching. The quality may be a function of a relative shift in the ordering sequence occurring between the one or more representative network measurement reports and calibration point cell power ordering. It is also envisioned that this same concept may be applied to any other vector parameter characterizing NMRs and/or grid points and such an example should not limit the scope of the claims appended herewith.

FIG. **65** is a diagram for a system for estimating the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **65**, at block **6510**, the system may comprise a database and, at block **6520**, a processor operably connected thereto for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also be programmed to receive an NMR from a mobile device at an unknown location. The processor may be programmed to determine a first region within the calibration data as a function of a first characterizing parameter of the received NMR and a predetermined range of the first parameter and repeat the determination for each characterizing parameter in the NMR at block **6521**, and determine an intersection for each defined region at block **6522**. The processor may be further programmed to estimate the location of a mobile device in the geographic region as a function of the intersection at block **6523**. Any one or plural calibration points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

FIG. **66** is a diagram for a system for estimating the location of a mobile device in a geographic region according to an additional embodiment of the present subject matter. With reference to FIG. **66**, at block **6610**, the system may comprise a database and, at block **6620**, a processor operably connected thereto for receiving calibration data for each of one or more calibration points in a geographic region where the calibration data may include at least one characterizing parameter. The processor may also receive a set of network measurement reports from a mobile device at an unknown location, at least one of the network measurement reports in the set may also include at least one characterizing parameter. The processor may be programmed to determine a representative value for each available characterizing parameter in the set as a function of a variation of the available characterizing parameter in each network measurement report in the set at block **6621** and determine one or more representative network measurement reports as a function of the representative value at block **6622**. At block **6623**, the processor may also be programmed to estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports.

In a further embodiment, the processor may be programmed to determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value and repeat said determination for each characterizing parameter in the one or more representative network measurement reports, determine an intersection of each determined region. The processor may also be programmed to estimate the location of a mobile device in the geographic region as a function of the intersection. Of course, any one or plural calibration points may be located on a predetermined fixed uniform grid defined over

the geographic region or randomly located within said geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one calibration point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one calibration point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the calibration points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors.

FIG. **67** is a flow chart for a method of determining the location of a mobile device in a geographic region according to one embodiment of the present subject matter. With reference to FIG. **67**, at block **6710**, the method may comprise providing calibration data for each of one or more calibration points in a geographic region where the calibration data includes one or more characterizing parameters. At block **6710**, at least one NMR from a mobile device at an unknown location may be received. Of course, a set of NMRs may also be received in another embodiment of the present subject matter. At block **6720**, one or more sets of grid points for the calibration data may be generated, and at block **6730**, the at least one network measurement report may be evaluated with each of the sets of grid points as a function of select ones of the characterizing parameters. A set of grid points may be selected as a function of a predetermined criteria at block **6740**, and at block **6750**, the location of a mobile device may be determined in the geographic region as a function of the selected set of grid points. Exemplary predetermined criteria may be, but are not limited to, total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance. Of course, any one or plural grid points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR. In one embodiment of the present subject matter for each of select ones of the grid points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors. An exemplary characterizing parameter (which may have been extracted from the calibration points that were assigned to the corresponding grid point) may be, but is not limited to, signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at the grid point, signal strength of a signal transmitted by a transmitter located at the grid point as received by a receiver at a known location, round trip time for a signal traveling between the grid point and a known location, timing advance of a signal received by the mobile device at the grid point, time difference of arrival of plural signals at the grid point with respect to a pair of known locations as measured by a receiver at the grid point or at the known locations, the identification of a serving cell or serving sector of the mobile device located at the grid point, a state of a wireless network serving the mobile device, and combinations thereof.

FIG. **68** is a flow chart for a method of determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to FIG. **68**, blocks **6810**, **6820**, **6830**, **6840**, and **6850** are similar to blocks **6710**, **6720**, **6730**, **6740**, and **6750**, respectively. At block **6831**, in one embodiment of the present subject matter the evaluation of the at least one NMR may include (i) comparing select ones of the sets of grid points to at least one characterizing parameter of the at least one NMR, (ii) generating a first location estimate of the mobile device for each parameter of the NMR, and (iii) determining a second location estimate of the mobile device as a function of at least one of the generated first location estimates. At block **6832**, another embodiment of the present subject matter may further comprise the step of identifying and omitting outlier first location estimates by (i) determining a Mahalanobis distance from each first location estimate to the second location estimate, (ii) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and (iii) determining a third location estimate by averaging two or more of the first location estimates. First location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold may be omitted from the determined third location estimate.

At block **6833**, embodiments of the present subject matter may determine a second location estimate by averaging two or more first location estimates, or omit a first location estimate having an error greater than a predetermined threshold, at block **6834**. At block **6835**, embodiments of the present subject matter may also determine a second location estimate by employing a weighted averaging of ones of the first location estimates, or at block **6836**, determine a second location estimate by weighting a first location estimate by an inverse of a distance metric. At block **6837**, embodiments of the present subject matter may also determine a second location estimate by normalizing a first location estimate by a sum of an inverse of a distance metric, or at block **6838**, determine a second location estimate by weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving the mobile device.

FIG. **69** is a flow chart for a method of determining the location of a mobile device in a geographic region according to a further embodiment of the present subject matter. With reference to FIG. **69**, blocks **6910**, **6920**, **6930**, **6940** and **6950** are similar to blocks **6710**, **6720**, **6730**, **6740**, and **6750**, respectively. At block **6931**, in one embodiment of the present subject matter the evaluation of the at least one NMR may include (i) comparing an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region where the ordering may be a function of any parameter of the NMR; and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, and any combination thereof.

At block **6932** in another embodiment of the present subject matter, the evaluation of the at least one NMR may include (i) comparing an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region where the ordering may be a function of any parameter of the NMR, (ii) if no exact match is made between the ordered list of neighboring cells of the NMR and any grid point in the geographic region then forming a largest subset of the ordered list of neighboring cells in the grid points that provide a

match, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

In another embodiment of the present subject matter, the evaluation of the at least one NMR may comprise at block **6933** (i) comparing an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, where the ordering may be a function of any parameter of the NMR, (ii) using a largest subset of neighboring cells in the NMR having either an exact match or is contained in the ordered list of neighboring cells in the geographic region if the ordered list of neighboring cells of the NMR is not contained in the ordered list of neighboring cells for the geographic region, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

At block **6934**, in another embodiment of the present subject matter the evaluation of the at least one NMR may include (i) evaluating a probability density function for each power level of a cell neighboring a cell serving the mobile device in the NMR over each grid point in a set of available grid points in the geographic region; (ii) determining a joint probability as a function of the individual pdfs, and (iii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

In an additional embodiment of the present subject matter, the evaluation of the at least one NMR may comprise at block **6935** (i) directly evaluating a joint probability (i.e., as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the NMR over a set of available grid points in the geographic region, and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof. At block **6936**, the evaluation of the at least one NMR may include in another embodiment of the present subject matter (i) determining a distortion measure between a parameter of a grid point and a corresponding parameter in the NMR, and (ii) generating an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the geographic region (where the weighted sum may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the geographic region, as a function of locations determined from subsets of the calibration data.

In a further embodiment of the present subject matter, the evaluation of the at least one NMR may include at block **6937** (i) matching cell power ordering of cells neighboring a cell serving the mobile device in the NMR to neighboring cell power ordering of grid points in the geographic region, and (ii) selecting an estimated location as a function of a quality of the matching. An exemplary quality may be, but is not limited to, a function of a relative shift in an ordering sequence occurring between the NMR and grid point cell power ordering. At block **6938**, the evaluation of the at least one NMR may comprise in another embodiment of the present subject matter (i) defining a first region within the calibration data as a function of a first characterizing parameter of the at least one NMR and a predetermined range of the first parameter, (ii) defining a second region within the calibration data as a function of another characterizing parameter of the at least one NMR and a predetermined range of the another parameter, and (iii) repeating steps (i)-(ii) for each characterizing parameter in the at least one NMR. The evaluation may further comprise (iv) determining an intersection of each defined region, and (v) estimating the location of a mobile device in the geographic region as a function of the intersection.

At block **6939**, the evaluation of the at least one NMR may also comprise (i) defining a first region within the calibration data as a function of a first characterizing parameter of a NMR within a set of NMRs and a predetermined range of the first parameter, (ii) defining a second region within the calibration data as a function of another characterizing parameter of the NMR within the set of NMRs and a predetermined range of the another parameter, and (iii) repeating steps (i)-(ii) for each characterizing parameter in the set of NMRs. The evaluation may further include (iv) determining a clustering of data vectors in the set of NMRs, and (v) estimating the location of a mobile device in the geographic region as a function of the clustering. At block **6941**, the evaluation of the at least one NMR may comprise in one embodiment of the present subject matter (i) determining a representative value for each available characterizing parameter in a set of NMRs as a function of a variation of available characterizing parameters in each available network measurement report, (ii) determin-

ing one or more representative network measurement reports as a function of the representative value, and (iii) estimating the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports. Another embodiment of the present subject matter may define a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of the first value and define a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of the second value. A multitude of regions may be defined for each characterizing parameter in the one or more representative network measurement reports. The method may further determine an intersection of each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

FIG. **70** is a diagram for a system for determining the location of a mobile device in a geographic region according to an embodiment of the present subject matter. With reference to FIG. **70**, the system may comprise at block **7010** a database, and at block **7020** a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one NMR from a mobile device at an unknown location in the geographic region. Of course, the calibration data and NMR may include at least one or plural characterizing parameters. At block **7021**, the processor may be programmed to (i) generate one or more sets of grid points for the calibration data, (ii) evaluate the at least one NMR with each of the sets of grid points as a function of select ones of the characterizing parameters, (iii) select a set of grid points as a function of a predetermined criteria, and (iv) determine the location of a mobile device in the geographic region as a function of the selected set. Of course, the at least one NMR may be plural NMRs such as a set of NMRs. Exemplary predetermined criteria may be, but are not limited to, total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance. Of course, any one or plural grid points may be located on a predetermined fixed uniform grid defined over the geographic region or randomly located within the geographic region. The calibration data may also comprise information from at least one NMR, may be obtained from one or more mobile devices located in close proximity to the one grid point, and/or may be obtained from a signal transmitted from a mobile device in close proximity to the one grid point and received at a receiver in or in proximity to the geographic region. In one embodiment of the present subject matter for each of select ones of the grid points, the calibration data may include plural data vectors and the evaluating of the calibration data may comprise a determination of clustering of the plural data vectors. An exemplary characterizing parameter (which may have been extracted from the calibration points that were assigned to the corresponding grid point) may be, but is not limited to, signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at the grid point, signal strength of a signal transmitted by a transmitter located at the grid point as received by a receiver at a known location, round trip time for a signal traveling between the grid point and a known location, timing advance of a signal received by the mobile device at the grid point, time difference of arrival of plural signals at the grid point with respect to a pair of known locations as measured by a receiver at the grid point or at the known locations, the identification of a serving cell or serving sector of the mobile device located at the grid point, a state of a wireless network serving the mobile device, and combinations thereof.

FIG. **71** is a diagram for a system for determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to FIG. **71**, blocks **7110**, **7120** and **7121** are similar to blocks **7010**, **7020** and **7021**, respectively. At block **7122**, in one embodiment of the present subject matter the processor may be programmed to (v) compare select ones of the sets of grid points to at least one characterizing parameter of the at least one NMR, (vi) generate a first location estimate of the mobile device for each parameter of the NMR, and (vii) determine a second location estimate of the mobile device as a function of at least one of the generated first location estimates. At block **7123**, in another embodiment of the present subject matter the processor may be programmed to identify and omit outlier first location estimates. The process may identify and omit outlier first location estimates by (1) determining a Mahalanobis distance from each first location estimate to the second location estimate, (2) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor, and (3) determining a third location estimate by averaging two or more of the first location estimates. First location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold may then be omitted from the determined third location estimate. At block **7124**, the processor, in one embodiment, may be programmed to determine an estimated location for the mobile device from the at least one NMR as a function of at least one characterizing parameter.

FIG. **72** is a diagram for a system for determining the location of a mobile device in a geographic region according to another embodiment of the present subject matter. With reference to FIG. **72**, blocks **7210** and **7220** are similar to blocks **7010** and **7020**, respectively. At block **7221**, in one embodiment of the present subject matter the processor may be programmed to (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, and (ii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, and any combination thereof.

At block **7222** in another embodiment of the present subject matter, the processor may be programmed, to (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, (ii) form a largest subset of the ordered list of neighboring cells in the geographic region if no exact match is made between the ordered list of neighboring cells of the NMR and any grid point in the geographic region, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the loca-

tions of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

In another embodiment of the present subject matter, the processor may be programmed to, at block **7223** (i) compare an ordered list of cells neighboring a cell serving the mobile device in the NMR to an ordered list of neighboring cells in each grid point of the geographic region, the ordering being a function of any parameter of the NMR, (ii) if the ordered list of neighboring cells of the NMR is not contained in the ordered list of neighboring cells for the geographic region then use a largest subset of neighboring cells in the NMR having either an exact match or is contained in the ordered list of neighboring cells in the geographic region, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a centroid of a cluster of matching grid points in the geographic region, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

At block **7224**, in another embodiment of the present subject matter the processor may be programmed to (i) evaluate a pdf for each power level of a cell neighboring a cell serving the mobile device in the NMR over each grid point in a set of available grid points in the geographic region, (ii) determine a joint probability as a function of the individual pdfs, and (iii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof.

In an additional embodiment of the present subject matter, the processor may be programmed to, at block **7225** (i) directly evaluate a joint probability (i.e., as an aggregate rather than through computation of the product of marginal pdfs) of power levels for at least one cell neighboring a cell serving the mobile device in the NMR over a set of available grid points in the geographic region, and (ii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a highest joint probability matching grid point in the geographic region, a weighted sum of the locations of a set of matching grid points in the geographic region (exemplary weights may be defined by any number of means such as, but not limited to, a joint probability derived from individual pdfs, etc.), a weighted sum of clustered locations of a set of matching grid points in the geographic region (i.e., cluster the locations of the matching grid points and then apply a cumulative probability for all contained grid points in a cluster as a weight for the respective cluster), as a function of locations determined from subsets of the calibration data, or any combination thereof. At block **7226**, the processor may be programmed to (i) determine a distortion measure between a parameter of a grid point and a corresponding parameter in the NMR, and (ii) generate an estimated location of the mobile device. The estimated location may be, but is not limited to, a location of a grid point having the smallest distortion measure, a weighted sum of the locations of a set of matching grid points in the geographic region (where the weighted sum may be a function of the distortion measure), a weighted sum of clustered locations of a set of matching grid points in the geographic region, as a function of locations determined from subsets of the calibration data.

In a further embodiment of the present subject matter, the processor may be programmed to, at block **7227** (i) match cell power ordering of cells neighboring a cell serving the mobile device in the NMR to neighboring cell power ordering of grid points in the geographic region, and (ii) select an estimated location as a function of a quality of the matching. An exemplary quality may be, but is not limited to, a function of a relative shift in an ordering sequence occurring between the NMR and grid point cell power ordering.

At block **7228**, in a further embodiment of the present subject matter the processor may be programmed to (v) determine a first region within the calibration data as a function of a first characterizing parameter of the at least one NMR and a predetermined range of said first parameter and repeat the determination for each characterizing parameter in the at least one NMR, (vi) determine an intersection for each defined region, and (vii) estimate the location of a mobile device in the geographic region as a function of the intersection.

In yet another embodiment of the present subject matter, the processor may be programmed to, at block **7229** (v) determine a first region within the calibration data as a function of a first characterizing parameter in a set of NMRs and a predetermined range of the first parameter and repeat the determination for each characterizing parameter in the set of NMRs, (vi) determine a clustering of data vectors of the set, by location, in the geographic region, and (vii) estimate the location of a mobile device in the geographic region as a function of the clustering. At block **7230**, the processor may also be programmed to in another embodiment of the present subject matter (v) determine a representative value for each available characterizing parameter in a set of NMRs as a function of a variation of available characterizing parameters in each available network measurement report, (vi) determine one or more representative NMRs as a function of the representative value, and (vii) estimate the location of a mobile device in the geographic region as a function of the one or more representative network measurement reports. A further embodiment of the processor may also determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value and repeat the determination for each characterizing parameter in the one or more representative network measurement reports. The processor may also determine an intersection of each defined region, and estimate the location of a mobile device in the geographic region as a function of the intersection.

As shown by the various configurations and embodiments illustrated in FIGS. **1-72**, a method and system for generating a location estimate using uniform and non-uniform grid points have been described.

While preferred embodiments of the present subject matter have been described, it is to be understood that the embodiments described are illustrative only and that the scope of the invention is to be defined solely by the appended claims when accorded a full range of equivalence, many variations and modifications naturally occurring to those of skill in the art from a perusal hereof.

We claim:

**1**. A method of determining the location of a mobile device in a geographic region comprising the steps of:

(a) providing calibration data for each of one or more calibration points in a geographic region, said calibration data having one or more characterizing parameters;

(b) generating one or more sets of grid points for said calibration data;

(c) receiving at least one network measurement report from a mobile device at an unknown location in said geographic region;

(d) evaluating said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters;

(e) selecting a set of grid points as a function of a predetermined criteria; and

(f) determining the location of a mobile device in said geographic region as a function of said selected set of grid points.

**2**. The method of claim **1** wherein said at least one network measurement report is a set of network measurement reports.

**3**. The method of claim **1** wherein said predetermined criteria is selected from the group consisting of: total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance.

**4**. The method of claim **1** wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region.

**5**. The method of claim **4** wherein one of said grid points is randomly located within said geographic region.

**6**. The method of claim **1** wherein one of said grid points is randomly located within said geographic region.

**7**. The method of claim **1** wherein said calibration data comprises information from a network measurement report.

**8**. The method of claim **1** wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said sets of grid points comprises a determination of clustering of said plural data vectors.

**9**. The method of claim **1** wherein said characterizing parameter is selected from the group consisting of: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at said grid point; signal strength of a signal transmitted by a transmitter located at said grid point as received by a receiver at a known location; round trip time for a signal traveling between said grid point and a known location; timing advance of a signal received by said mobile device at said grid point; time difference of arrival of plural signals at said grid point with respect to a pair of known locations as measured by a receiver at said grid point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said grid point; a state of a wireless network serving said mobile device, and combinations thereof.

**10**. The method of claim **1** wherein the step of evaluating further comprises:

(i) comparing select ones of said sets of grid points to at least one characterizing parameter of said at least one network measurement report;

(ii) generating a first location estimate of the mobile device for each parameter of said network measurement report; and

(iii) determining a second location estimate of the mobile device as a function of at least one of said generated first location estimates.

**11**. The method of claim **10** further comprising the step of identifying and omitting outlier first location estimates by:

(i) determining a Mahalanobis distance from each first location estimate to the second location estimate;

(ii) determining a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor; and

(iii) determining a third location estimate by averaging two or more of said first location estimates,

wherein first location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold are omitted from said determined third location estimate.

**12**. The method of claim **10** wherein determining a second location estimate further comprises averaging two or more first location estimates.

**13**. The method of claim **10** further comprising the step of omitting a first location estimate having an error greater than a predetermined threshold.

**14**. The method of claim **10** wherein determining a second location estimate further comprises employing a weighted averaging of ones of said first location estimates.

**15**. The method of claim **10** wherein determining a second location estimate further comprises weighting a first location estimate by an inverse of a distance metric.

**16**. The method of claim **10** wherein determining a second location estimate further comprises normalizing a first location estimate by a sum of an inverse of a distance metric.

**17**. The method of claim **10** wherein determining a second location estimate further comprises weighting a first location estimate as a function of the number of reporting neighboring cells to a serving cell serving said mobile device.

**18**. The method of claim **1** wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**19**. The method of claim **1** wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid

point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(ii) if no exact match is made between the ordered list of neighboring cells of said network measurement report and any grid point in said geographic region then forming a largest subset of the ordered list of neighboring cells in said grid points that provide a match; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**20**. The method of claim **1** wherein the step of evaluating further comprises:

(i) comparing an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(ii) if the ordered list of neighboring cells of said network measurement report is not contained in the ordered list of neighboring cells for said geographic region then using a largest subset of neighboring cells in said network measurement report having either an exact match or is contained in the ordered list of neighboring cells in said geographic region; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**21**. The method of claim **1** wherein the step of evaluating further comprises:

(i) evaluating a probability density function for each power level of a cell neighboring a cell serving said mobile device in said network measurement report over each grid point in a set of available grid points in said geographic region;

(ii) determining a joint probability as a function of said individual probability density functions; and

(iii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**22**. The method of claim **1** wherein the step of evaluating further comprises:

(i) evaluating a joint probability of power levels for at least one cell neighboring a cell serving said mobile device in said network measurement report over a set of available grid points in said geographic region; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**23**. The method of claim **1** wherein the step of evaluating further comprises:

(i) determining a distortion measure between a parameter of a grid point and a corresponding parameter in said network measurement report; and

(ii) generating an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a location of a grid point having the smallest distortion measure; a weighted sum of the locations of a set of matching grid points in said geographic region, said weighted sum being a function of said distortion measure; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**24**. The method of claim **1** wherein the step of evaluating further comprises:

(i) matching cell power ordering of cells neighboring a cell serving said mobile device in said network measurement report to neighboring cell power ordering of grid points in said geographic region; and

(ii) selecting an estimated location as a function of a quality of said matching,

wherein said quality is a function of a relative shift in an ordering sequence occurring between said network measurement report and grid point cell power ordering.

**25**. The method of claim **1** wherein the step of evaluating further comprises:

(i) defining a first region within said calibration data as a function of a first characterizing parameter of said at least one network measurement report and a predetermined range of said first parameter;

(ii) defining a second region within said calibration data as a function of another characterizing parameter of said at least one network measurement report and a predetermined range of said another parameter;

(iii) repeating steps (i)-(ii) for each characterizing parameter in said at least one network measurement report;

(iv) determining an intersection of each defined region; and

(v) estimating the location of a mobile device in said geographic region as a function of said intersection.

**26**. The method of claim **1** wherein the step of evaluating further comprises:

(i) defining a first region within said calibration data as a function of a first characterizing parameter of a network measurement report within a set of network measurement reports and a predetermined range of said first parameter;

(ii) defining a second region within said calibration data as a function of another characterizing parameter of said network measurement report within the set of network measurement reports and a predetermined range of said another parameter;

(iii) repeating steps (i)-(ii) for each characterizing parameter in said set of network measurement reports;

(iv) determining a clustering of data vectors in said set of network measurement reports; and

(v) estimating the location of a mobile device in said geographic region as a function of said clustering.

**27**. The method of claim **1** wherein the step of evaluating further comprises:

(i) determining a representative value for each available characterizing parameter in a set of network measurement reports as a function of a variation of said available characterizing parameter in each available network measurement report;

(ii) determining one or more representative network measurement reports as a function of said representative value; and

(iii) estimating the location of a mobile device in said geographic region as a function of said one or more representative network measurement reports.

**28**. The method of claim **27** further comprising the steps of:

(iv) defining a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value;

(v) defining a second region as a function of a second representative value for a second characterizing parameter and a predetermined range of said second value;

(vi) repeating steps (iv)-(v) for each characterizing parameter in said one or more representative network measurement reports;

(vii) determining an intersection of each defined region; and

(viii) estimating the location of a mobile device in said geographic region as a function of said intersection.

**29**. The method of claim **1** wherein the step of selecting further comprises selecting a set of grid points as a function of a criteria of fit.

**30**. The method of claim **29** wherein the criteria of fit is selected from the group consisting of: total probability, cluster radius, Euclidean norm, Mahalanobis distance, distortion measure, confidence measure, and any combination thereof.

**31**. The method of claim **1** wherein the step of selecting further comprises:

(i) selecting one or more candidate locations from one or more of said sets of grid points; and

(ii) evaluating said selected one or more candidate locations across said one or more sets of grid points,

wherein the determined location of the mobile device is a function of said evaluation of said selected locations.

**32**. A system for determining the location of a mobile device in a geographic region comprising:

(a) a database; and

(b) a processor for receiving calibration data for each of one or more calibration points in a geographic region and receiving at least one network measurement report from a mobile device at an unknown location in said geographic region, said calibration data and network measurement report having at least one characterizing parameter and said processor is programmed to:

(i) generate one or more sets of grid points for said calibration data,

(ii) evaluate said at least one network measurement report with each of said sets of grid points as a function of select ones of said characterizing parameters,

(iii) select a set of grid points as a function of a predetermined criteria, and

(iv) determine the location of a mobile device in said geographic region as a function of said selected set.

**33**. The system of claim **32** wherein said at least one network measurement report is a set of network measurement reports.

**34**. The system of claim **32** wherein said predetermined criteria is selected from the group consisting of: total probability, cluster radius, Euclidean norm, joint probability, and Mahalanobis distance.

**35**. The system of claim **32** wherein one of said grid points is located on a predetermined fixed uniform grid defined over said geographic region.

**36**. The system of claim **35** wherein one of said grid points is randomly located within said geographic region.

**37**. The system of claim **32** wherein one of said grid points is randomly located within said geographic region.

**38**. The system of claim **32** wherein said calibration data comprises information from a network measurement report.

**39**. The system of claim **32** wherein for each of select ones of said grid points the calibration data includes plural data vectors and the evaluating of said grid points comprises a determination of clustering of said plural data vectors.

**40**. The system of claim **32** wherein said characterizing parameter is selected from the group consisting of: signal strength for a signal transmitted by a transmitter having a known location as received by a receiver at said grid point; signal strength of a signal transmitted by a transmitter located at said grid point as received by a receiver at a known location; round trip time for a signal traveling between said grid point and a known location; timing advance of a signal received by said mobile device at said grid point; time difference of arrival of plural signals at said grid point with respect to a pair of known locations as measured by a receiver at said grid point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said grid point; a state of a wireless network serving said mobile device, and combinations thereof.

**41**. The system of claim **32** wherein the processor is further programmed to:

(v) compare select ones of said sets of grid points to at least one characterizing parameter of said at least one network measurement report;

(vi) generate a first location estimate of the mobile device for each parameter of said network measurement report; and

(vii) determine a second location estimate of the mobile device as a function of at least one of said generated first location estimates.

**42**. The system of claim **41** wherein the processor is further programmed to identify and omit outlier first location estimates by:

(1) determine a Mahalanobis distance from each first location estimate to the second location estimate;

(2) determine a distance threshold from a median of the Mahalanobis distances multiplied by a predetermined factor; and

(3) determine a third location estimate by averaging two or more of said first location estimates,

wherein first location estimates having a Mahalanobis distance to the second location estimate greater than the distance threshold are omitted from said determined third location estimate.

**43**. The system of claim **32** wherein the processor is further programmed to:

(v) determine an estimated location for said mobile device from said at least one network measurement report as a function of at least one characterizing parameter.

**44**. The system of claim **32** wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**45**. The system of claim **32** wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(vi) if no exact match is made between the ordered list of neighboring cells of said network measurement report and any grid point in said geographic region then form a largest subset of the ordered list of neighboring cells in said grid points that provide a match; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**46**. The system of claim **32** wherein the processor is further programmed to:

(v) compare an ordered list of cells neighboring a cell serving said mobile device in said network measurement report to an ordered list of neighboring cells in each grid point of said geographic region, said ordering being a function of any parameter of said network measurement report;

(vi) if the ordered list of neighboring cells of said network measurement report is not contained in the ordered list of neighboring cells for said geographic region then use a largest subset of neighboring cells in said network measurement report having either an exact match or is contained in the ordered list of neighboring cells in said geographic region; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a centroid of a cluster of matching grid points in said geographic region; a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**47**. The system of claim **32** wherein the processor is further programmed to:

(v) evaluate a probability density function for each power level of a cell neighboring a cell serving said mobile device in said network measurement report over each grid point in a set of available grid points in said geographic region;

(vi) determine a joint probability as a function of said individual probability density functions; and

(vii) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**48**. The system of claim **32** wherein the processor is further programmed to:

(v) evaluate a joint probability of power levels for at least one cell neighboring a cell serving said mobile device in said network measurement report over a set of available grid points in said geographic region; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a highest joint probability matching grid point in said geographic region; a weighted sum of the locations of a set of matching grid points in said geographic region; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**49**. The system of claim **32** wherein the processor is further programmed to:

(v) determine a distortion measure between a parameter of a grid point and a corresponding parameter in said network measurement report; and

(vi) generate an estimated location of said mobile device wherein said estimated location is selected from the group consisting of: a location of a grid point having the smallest distortion measure; a weighted sum of the locations of a set of matching grid points in said geographic region, said weighted sum being a function of said distortion measure; a weighted sum of clustered locations of a set of matching grid points in said geographic region; and as a function of locations determined from subsets of said calibration data.

**50**. The system of claim **32** wherein the processor is further programmed to:

(v) match cell power ordering of cells neighboring a cell serving said mobile device in said network measurement report to neighboring cell power ordering of grid points in said geographic region; and

(vi) selecting an estimated location as a function of a quality of said matching,

wherein said quality is a function of a relative shift in an ordering sequence occurring between said network measurement report and grid point cell power ordering.

**51**. The system of claim **32** wherein the processor is further programmed to:

(v) determine a first region within said calibration data as a function of a first characterizing parameter of said at least one network measurement report and a predetermined range of said first parameter and repeat said determination for each characterizing parameter in said at least one network measurement report;

(vi) determine an intersection for each defined region; and

(vii) estimate the location of a mobile device in said geographic region as a function of said intersection.

**52**. The system of claim **32** wherein the processor is further programmed to:

(v) determine a first region within said calibration data as a function of a first characterizing parameter in a set of network measurement reports and a predetermined range of said first parameter and repeat said determination for each characterizing parameter in said set of network measurement reports;

(vi) determine a clustering of data vectors of said set, by location, in said geographic region; and

(vii) estimate the location of a mobile device in said geographic region as a function of said clustering.

**53**. The system of claim **32** wherein the processor is further programmed to:

(v) determine a representative value for each available characterizing parameter in a set of network measurement reports as a function of a variation of available characterizing parameters in each available network measurement report;

(vi) determine one or more representative network measurement reports as a function of said representative value; and

(vii) estimate the location of a mobile device in said geographic region as a function of said one or more representative network measurement reports.

**54**. The system of claim **53** wherein the processor is further programmed to:

(viii) determine a first region as a function of a first representative value for a first characterizing parameter and a predetermined range of said first value and repeat said determination for each characterizing parameter in said one or more representative network measurement reports;

(ix) determine an intersection of each defined region; and

(x) estimate the location of a mobile device in said geographic region as a function of said intersection.

**55**. The system of claim **32** wherein the processor is further programmed to select a set of grid points as a function of a criteria of fit.

**56**. The system of claim **55** wherein the criteria of fit is selected from the group consisting of: total probability, cluster radius, Euclidean norm, Mahalanobis distance, distortion measure, confidence measure, and any combination thereof.

**57**. The system of claim **32** wherein the processor is further programmed to:

(i) select one or more candidate locations from one or more of said sets of grid points; and

(ii) evaluate said selected one or more candidate locations across said one or more sets of grid points,

wherein the determined location of the mobile device is a function of said evaluated selected locations.

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# UNITED STATES COURT OF APPEALS
# FOR THE FEDERAL CIRCUIT

## CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATIONS

**Case Number:** 2024-1003, 2024-1018

**Short Case Caption:** Geoscope Technologies Pte., Ltd. v. Google LLC, Apple, Inc.

**Instructions:** When computing a word, line, or page count, you may exclude any items listed as exempted under Fed. R. App. P. 5(c), Fed. R. App. P. 21(d), Fed. R. App. P. 27(d)(2), Fed. R. App. P. 32(f), or Fed. Cir. R. 32(b)(2).

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Date: 11/17/2023

Signature: /s/ Timothy K. Gilman

Name: Timothy K. Gilman