US008175620B2

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Carlson et al.

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(54) **SYSTEM AND METHOD FOR GENERATING NON-UNIFORM GRID POINTS FROM CALIBRATION DATA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 796 days.

(21) Appl. No.: **12/068,213**

(22) Filed: **Feb. 4, 2008**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
H04W 24/00 (2009.01)

(52) **U.S. Cl.** **455/456.6**; 455/414; 455/456.3

(58) **Field of Classification Search** 455/404.2, 455/414.2, 456.1–457
See application file for complete search history.

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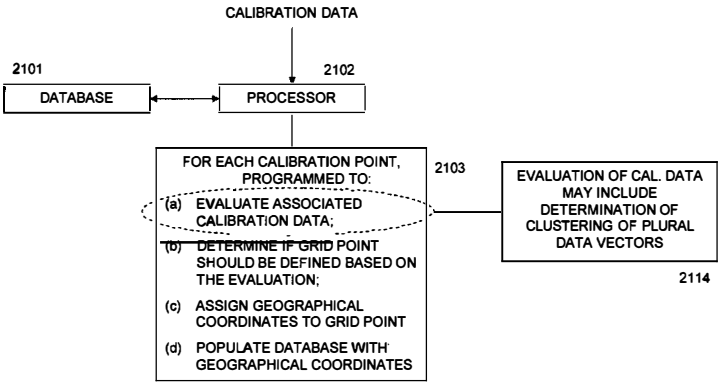
(74) *Attorney, Agent, or Firm* — Duane Morris, LLP

(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. Received signal level measurements reported by a mobile device for which a location estimate is to be determined may be compared with the data associated with the various grid points to estimate the location of the mobile device.

41 Claims, 28 Drawing Sheets



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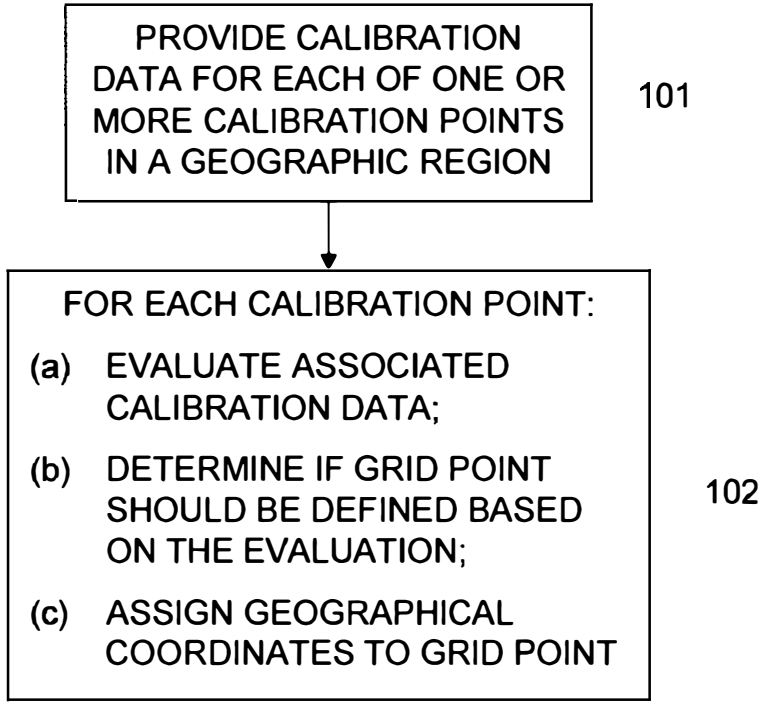
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
101
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
102

FIGURE 1

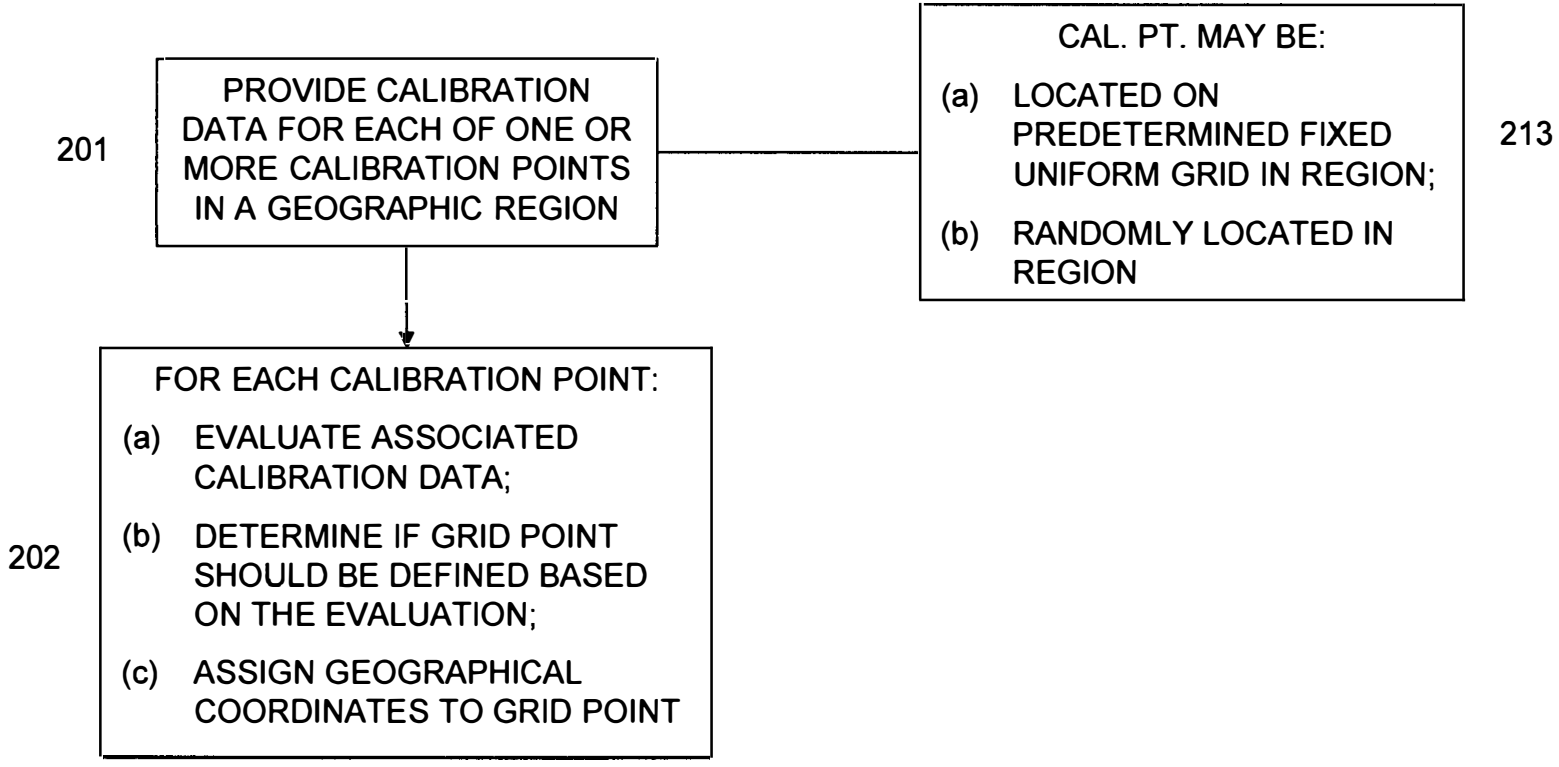
201
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
CAL. PT. MAY BE:
(a) LOCATED ON PREDETERMINED FIXED UNIFORM GRID IN REGION;
(b) RANDOMLY LOCATED IN REGION
213
202
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT

FIGURE 2

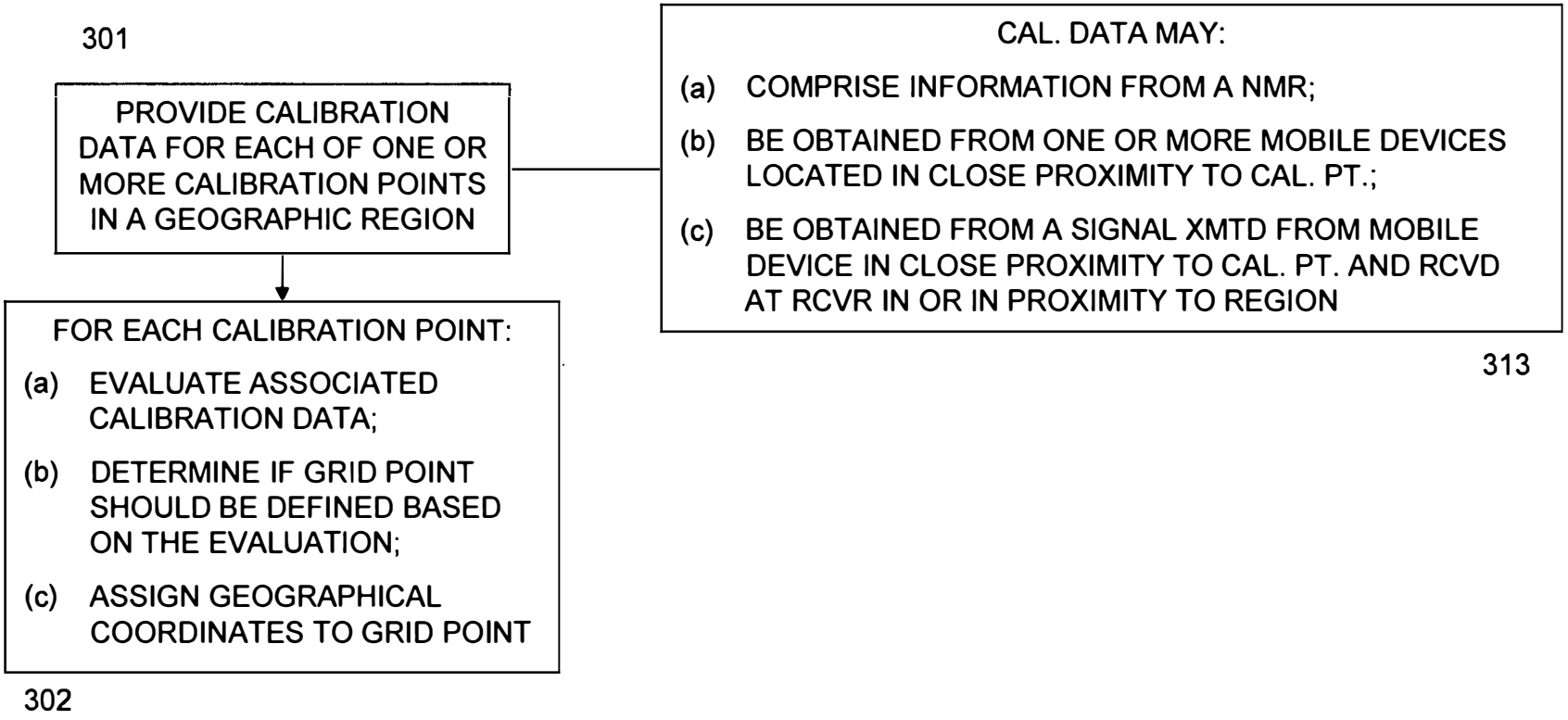
301
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
302
CAL. DATA MAY:
(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

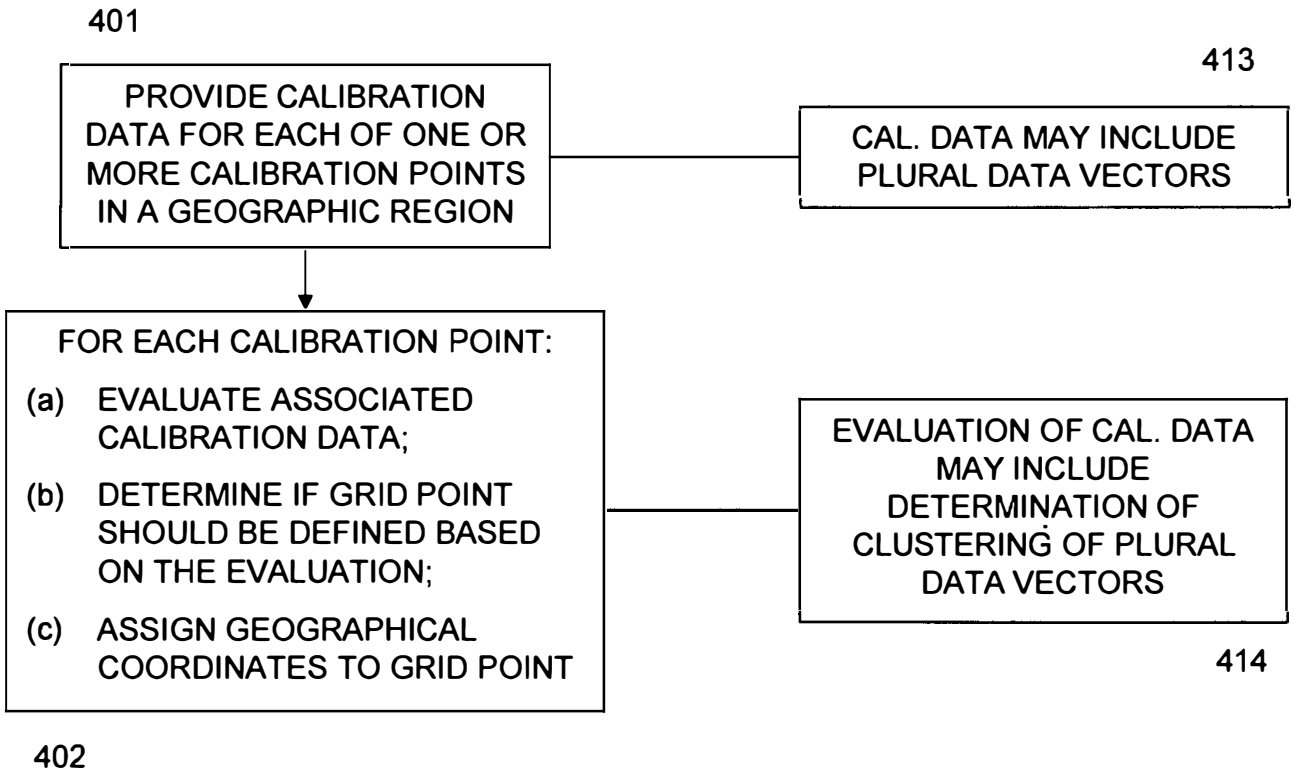
401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
413
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
414
402

FIGURE 4

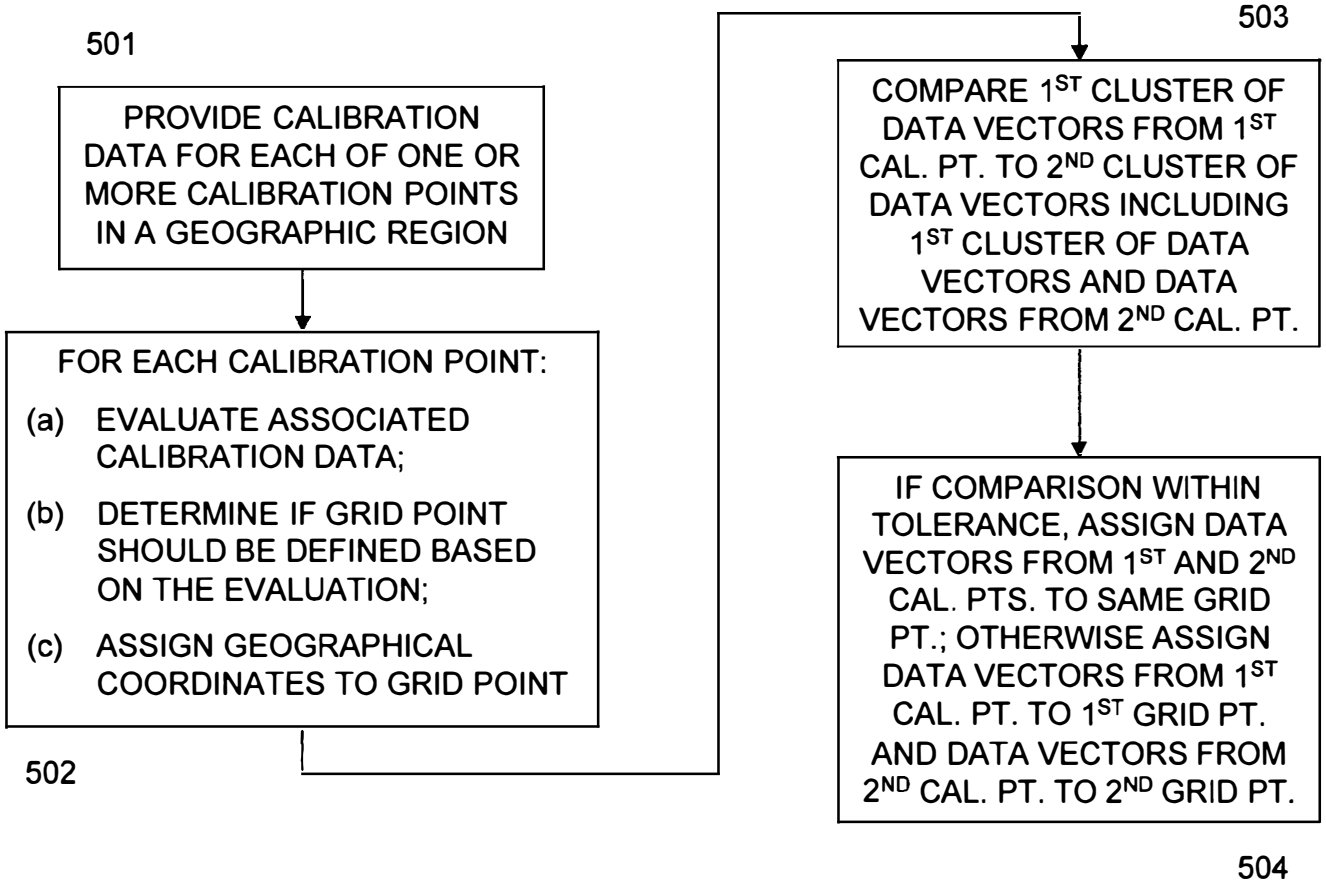
501
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
502
503
COMPARE 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.
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.
504

FIGURE 5

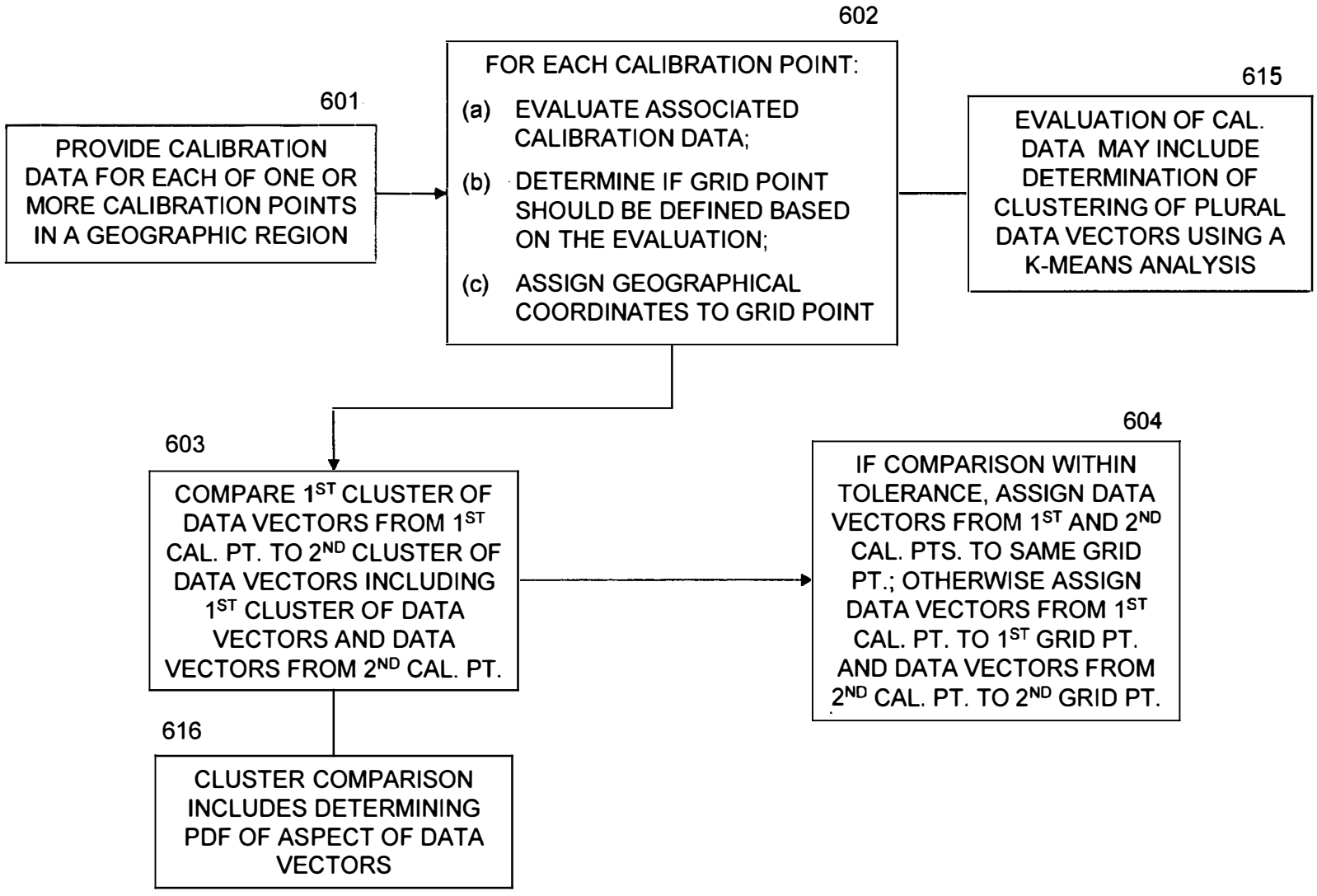
601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
615
EVALUATION 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

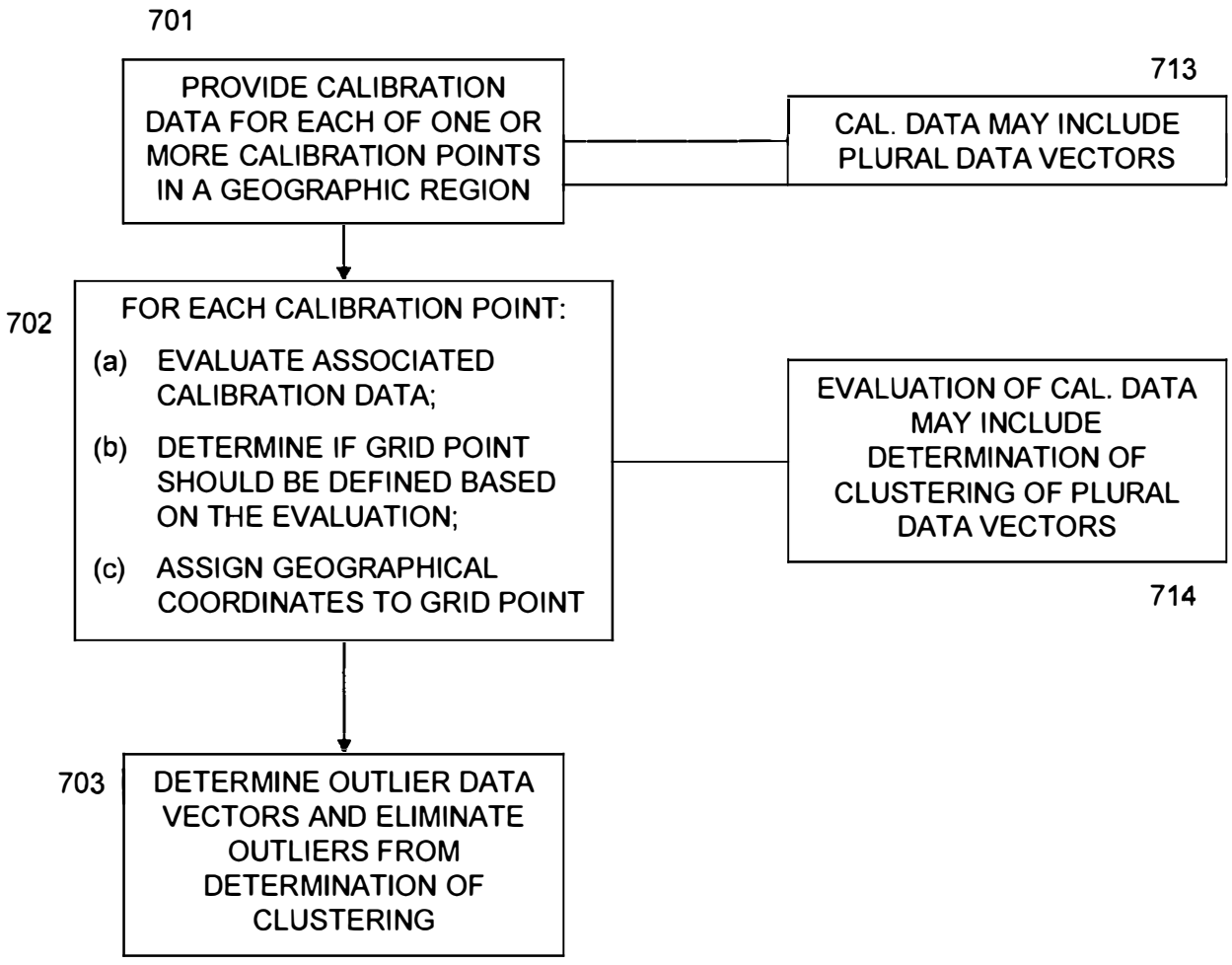
701
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
713
CAL. DATA MAY INCLUDE PLURAL DATA VECTORS
702
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
714
703
DETERMINE OUTLIER DATA VECTORS AND ELIMINATE OUTLIERS FROM DETERMINATION OF CLUSTERING

FIGURE 7

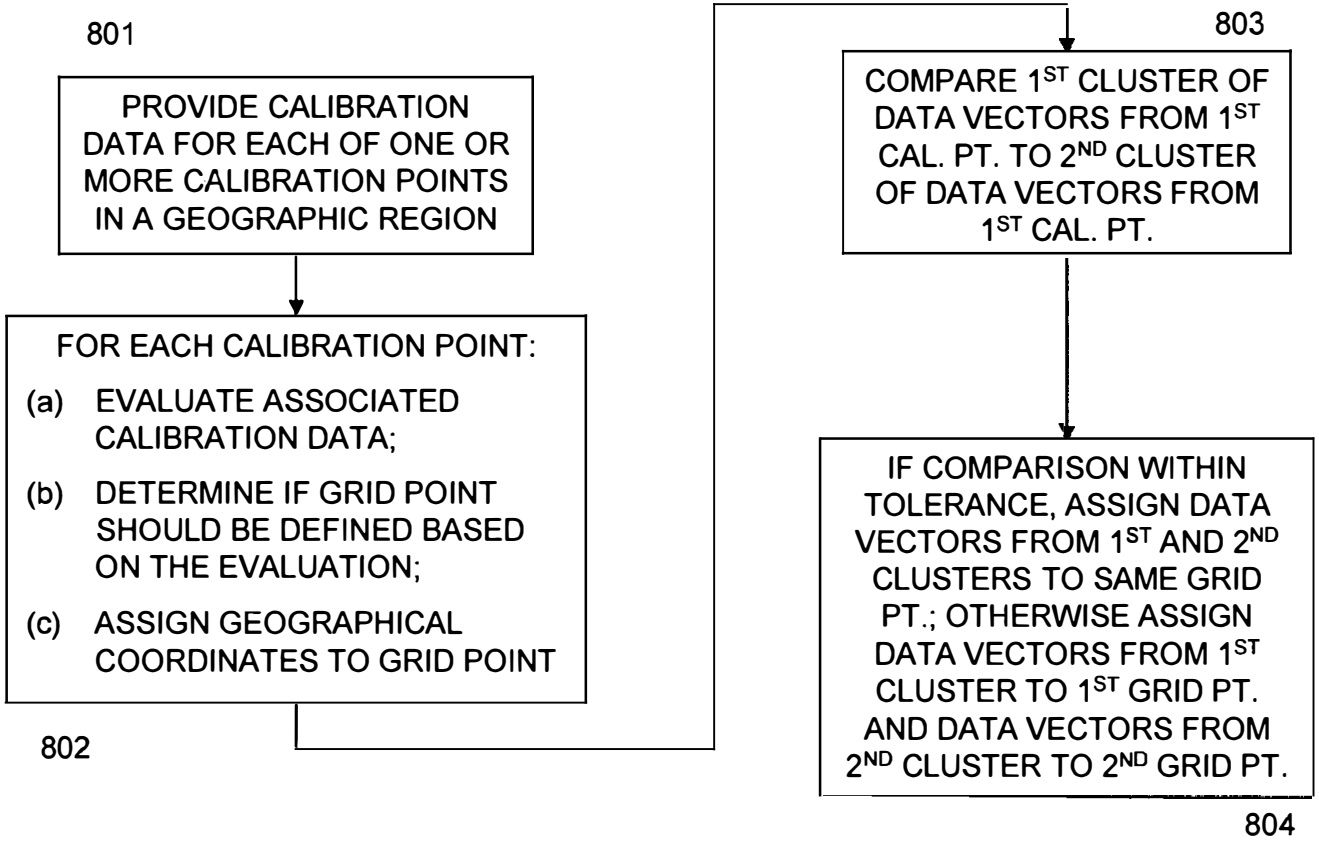
801
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
802
803
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
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.
804

FIGURE 8

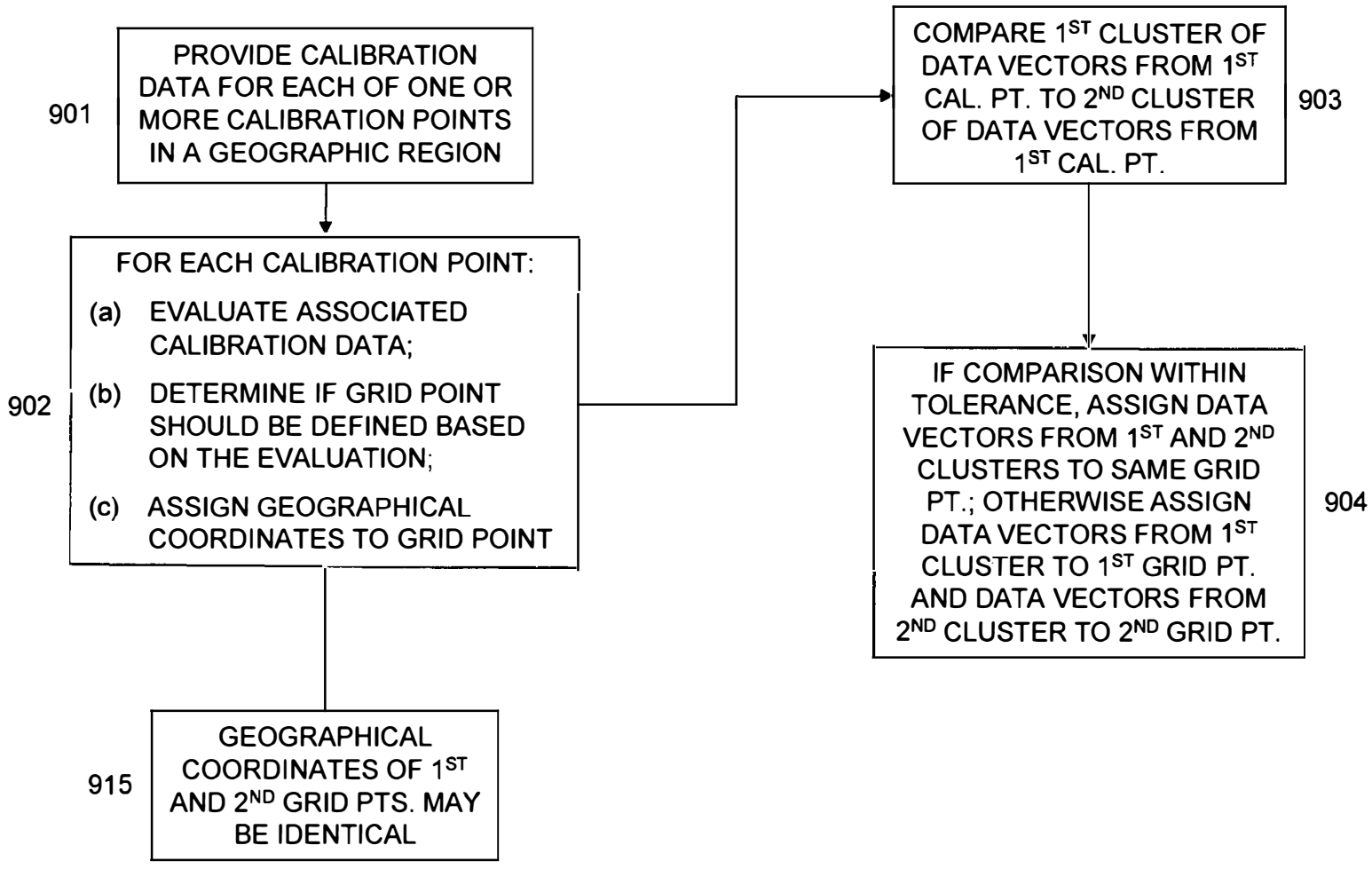
901
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
902
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
903
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
904
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.
915
GEOGRAPHICAL COORDINATES OF 1ST AND 2ND GRID PTS. MAY BE IDENTICAL

FIGURE 9

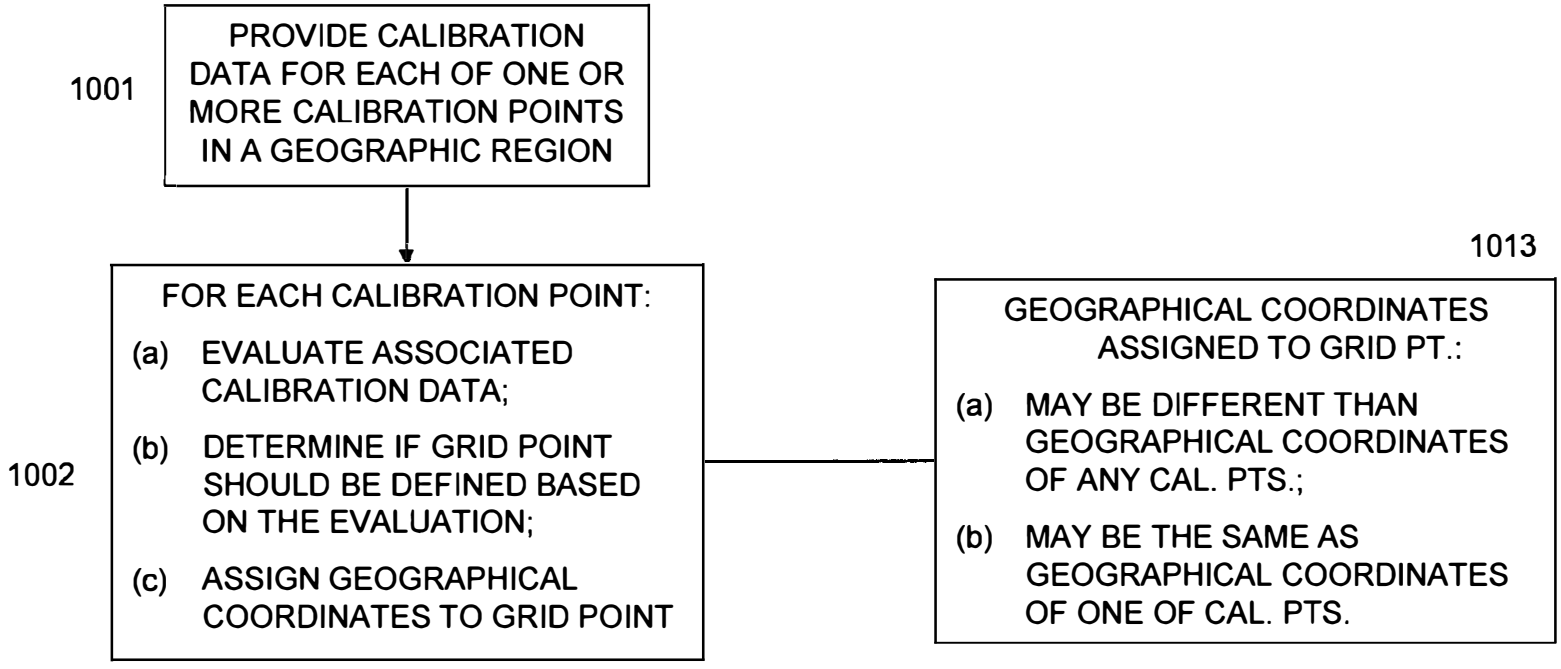
1001
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1002
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1013
GEOGRAPHICAL 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

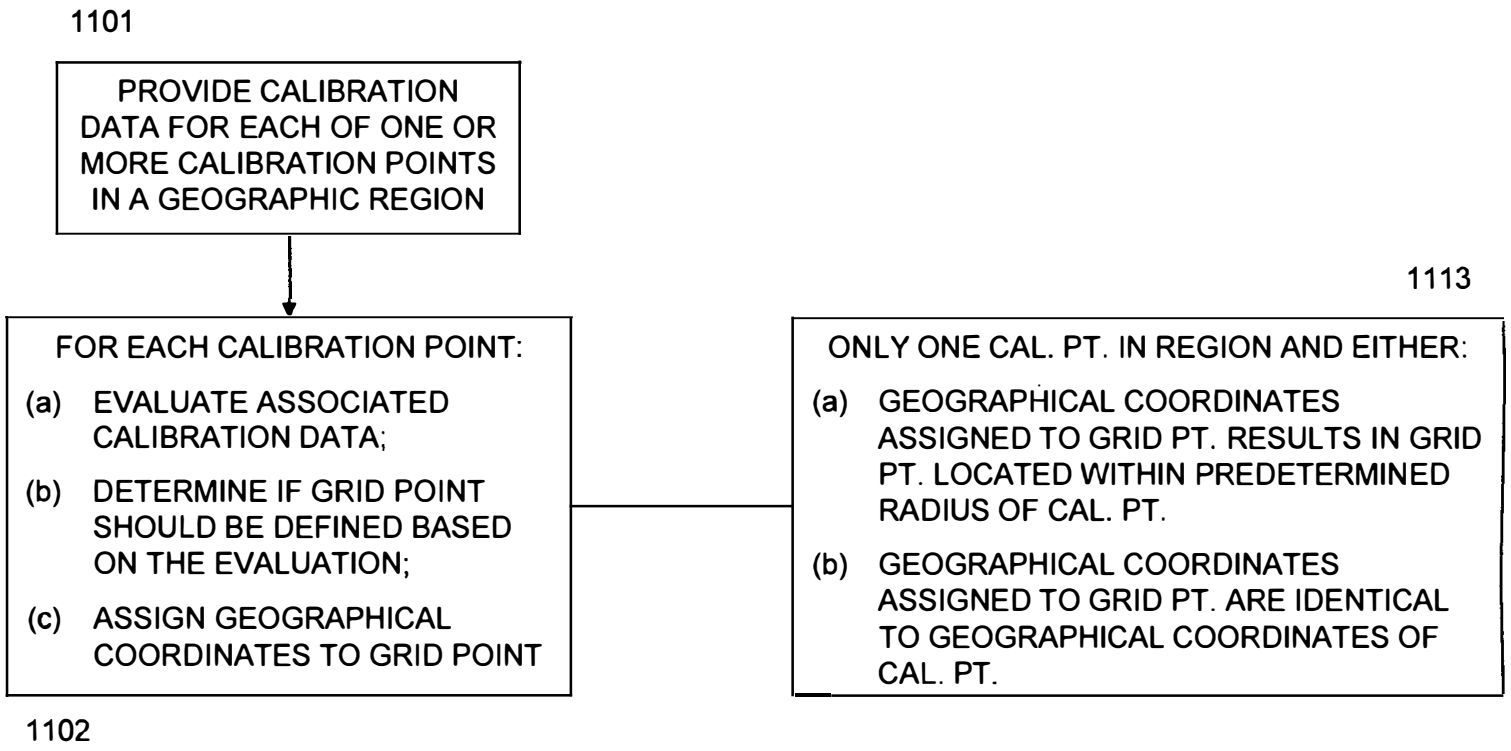
1101
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1102
1113
ONLY 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

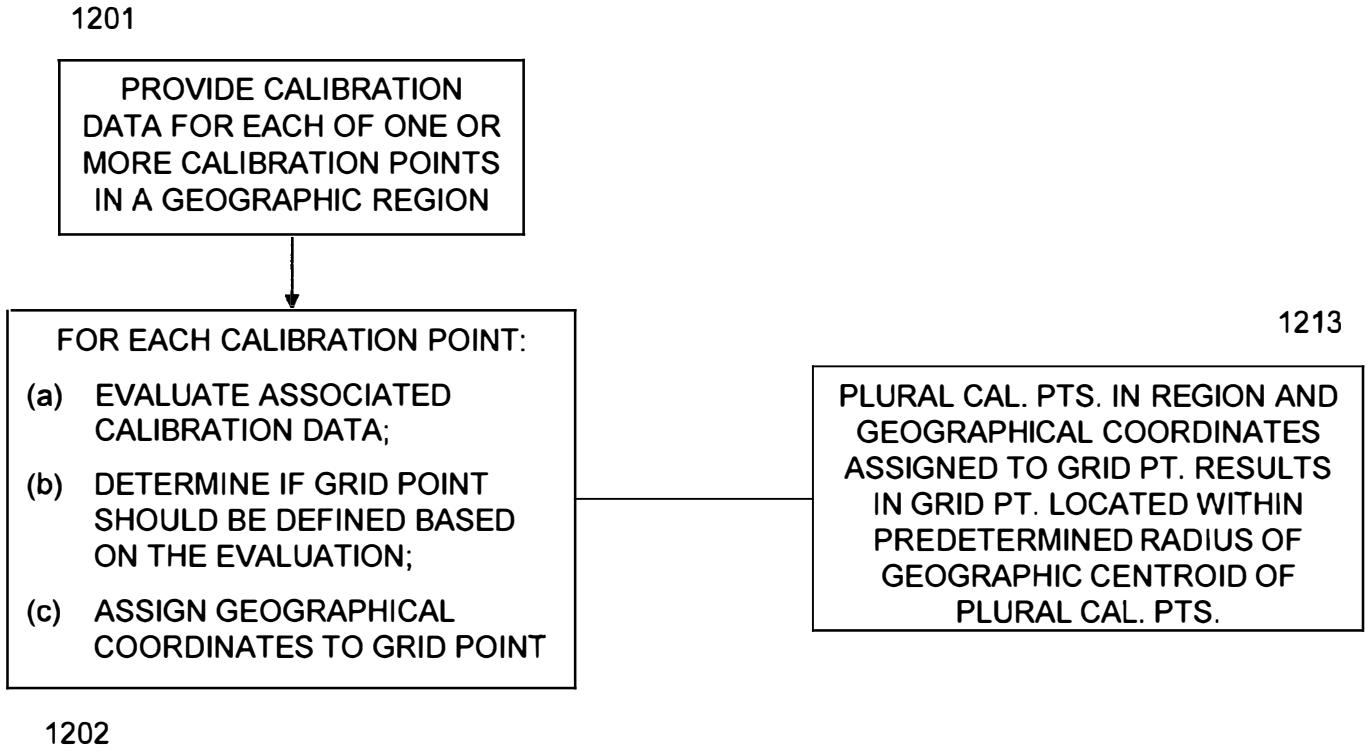
1201
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1202
1213
PLURAL 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

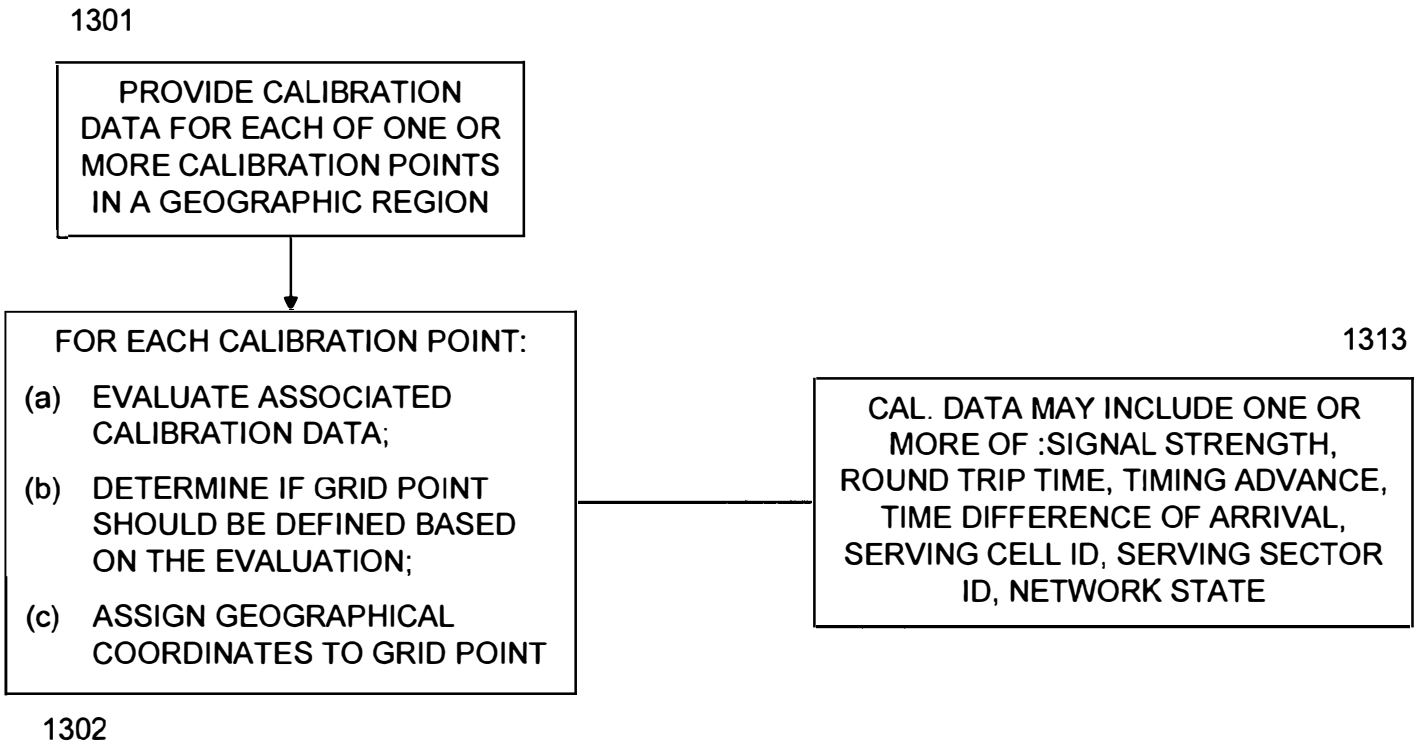
1301
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1302
1313
CAL. 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

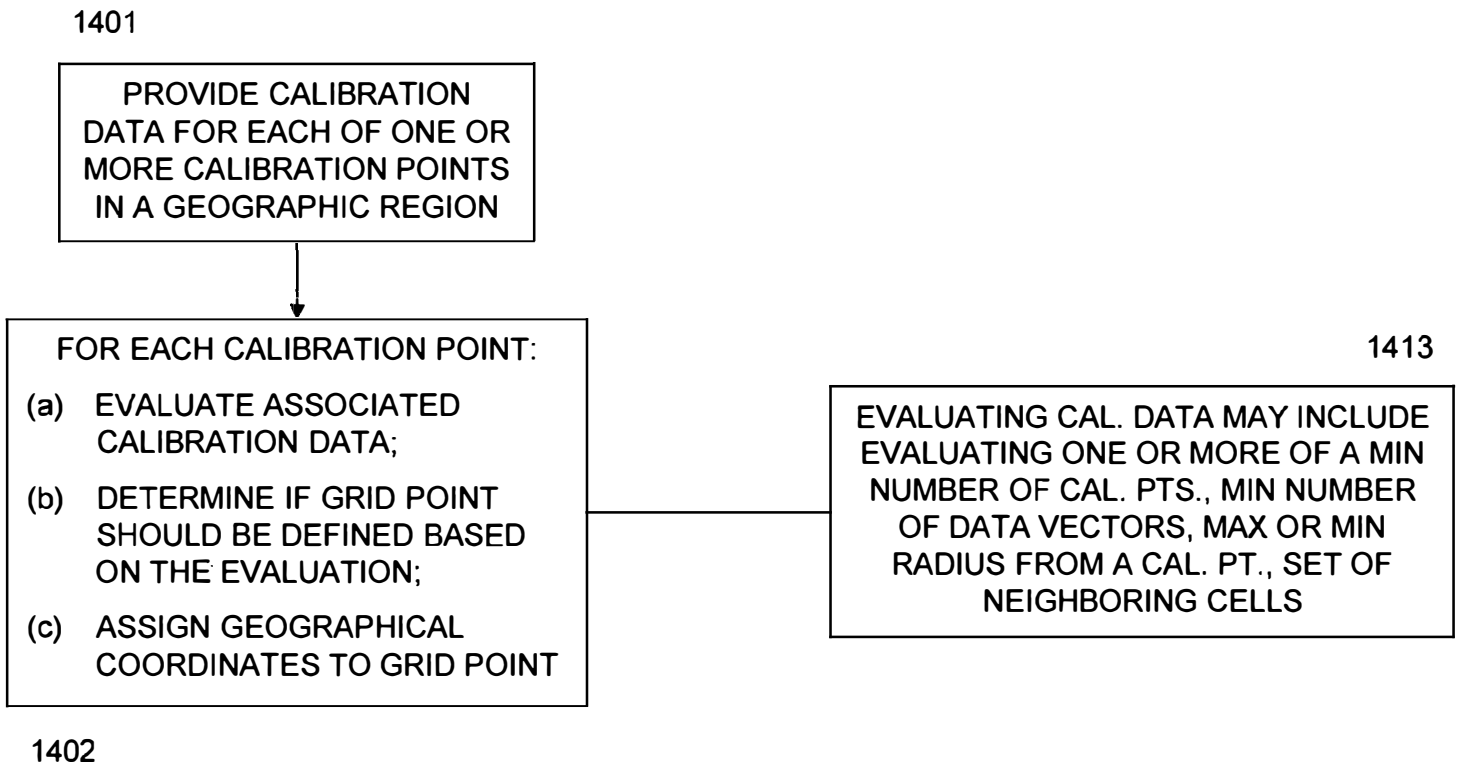
1401
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1402
1413
EVALUATING 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

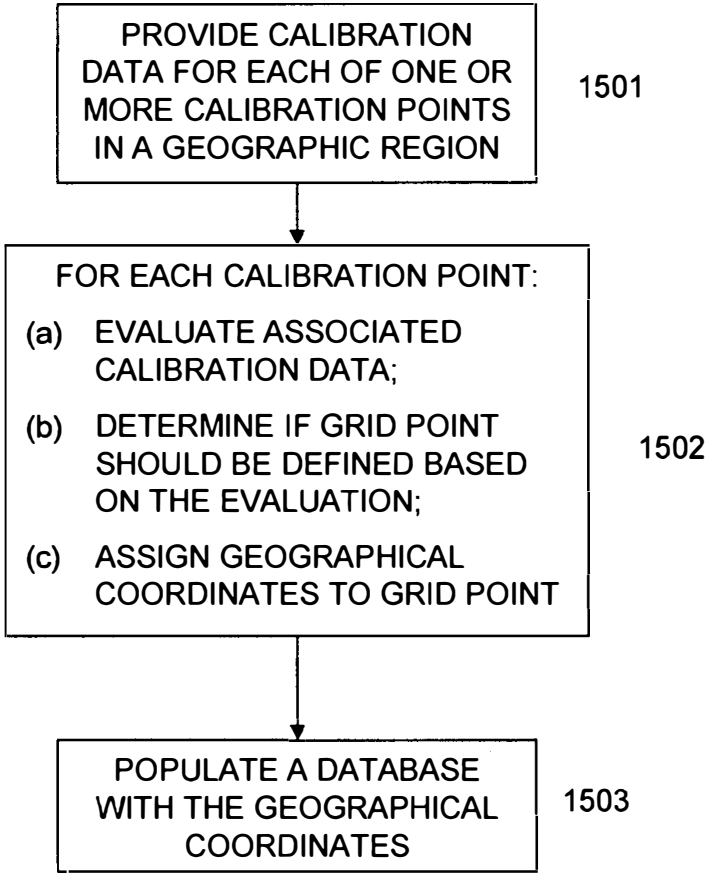
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1501
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1502
POPULATE A DATABASE WITH THE GEOGRAPHICAL COORDINATES
1503

FIGURE 15

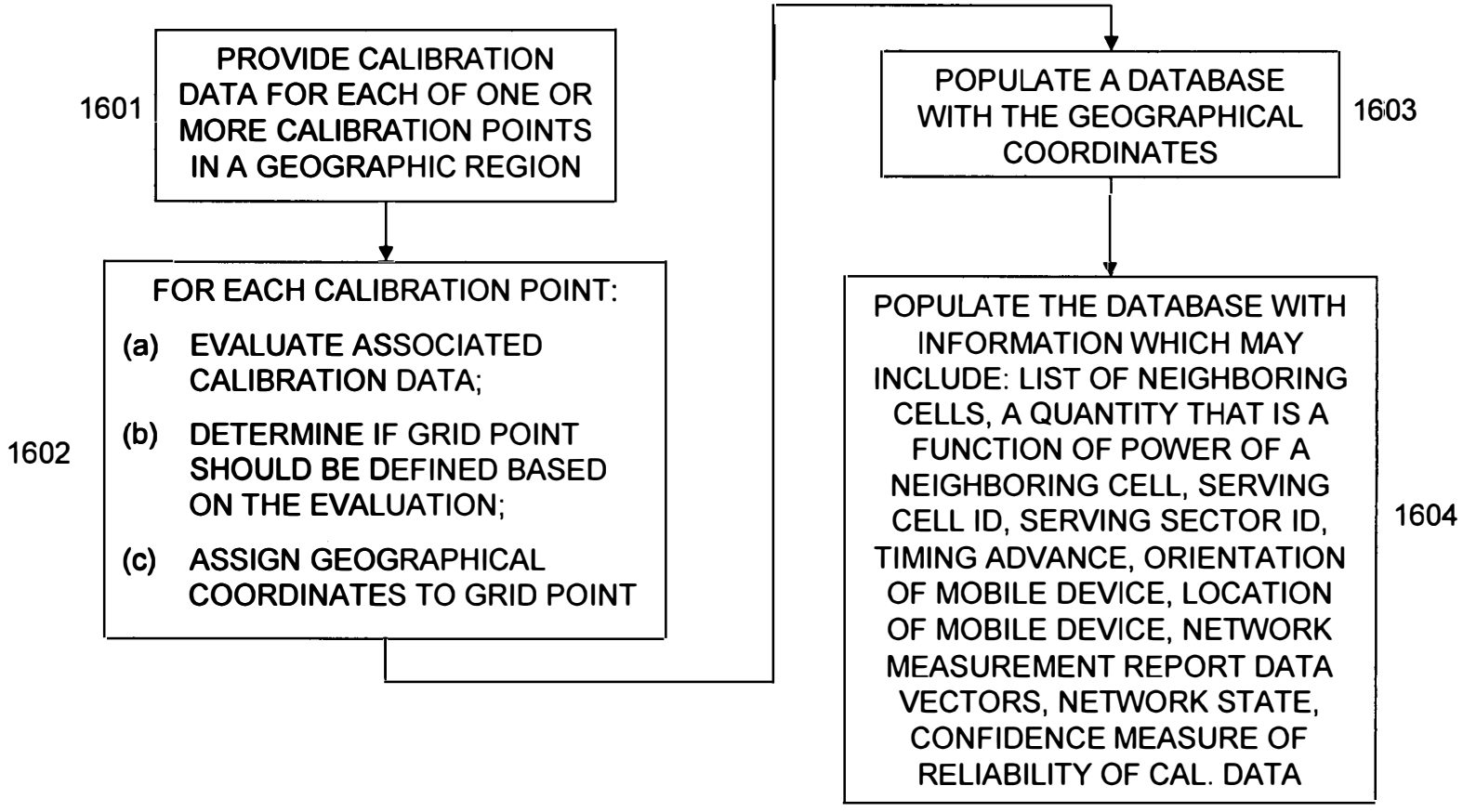
1601
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1602
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1603
POPULATE 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

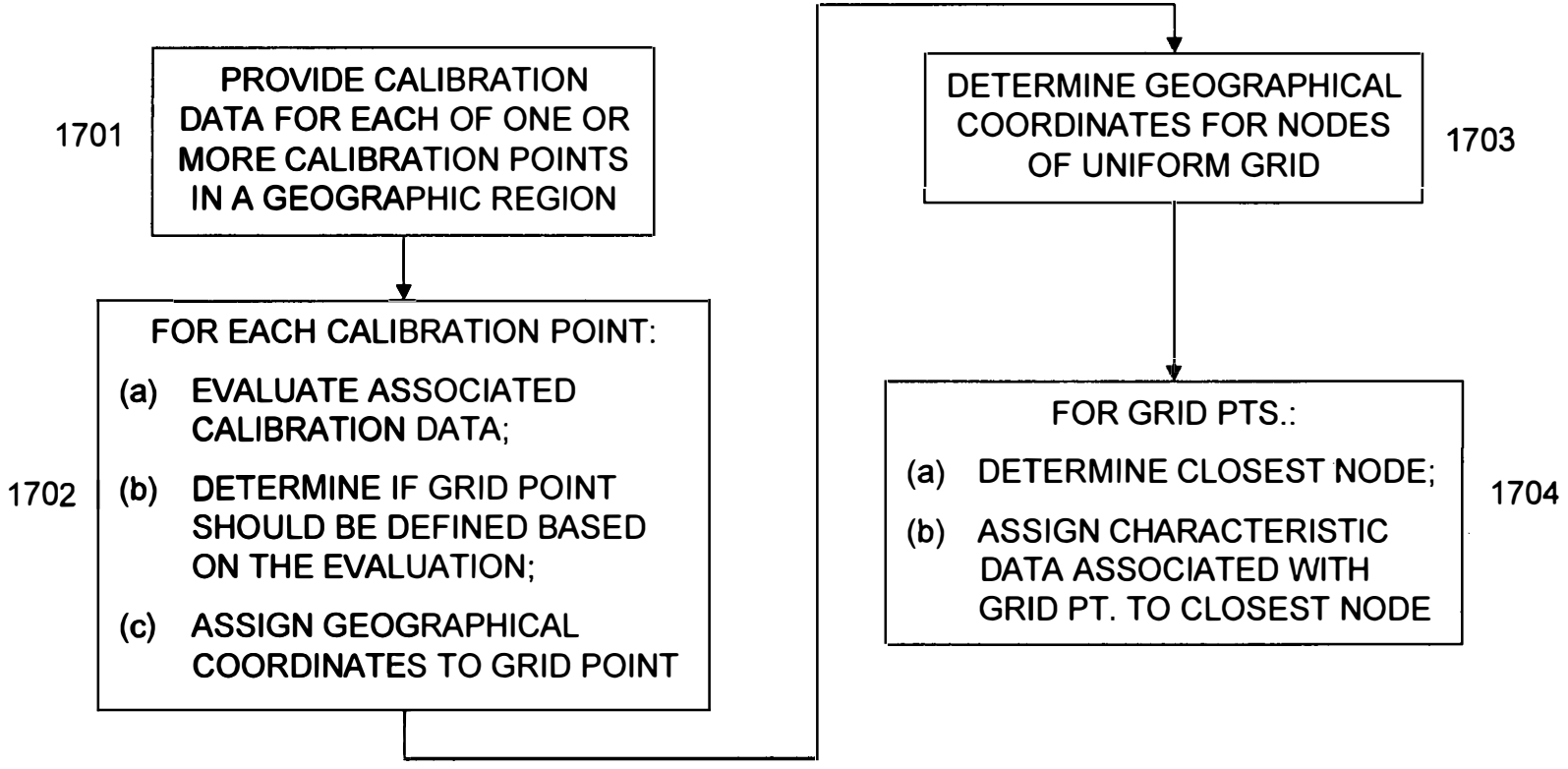
1701
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1702
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1703
DETERMINE 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

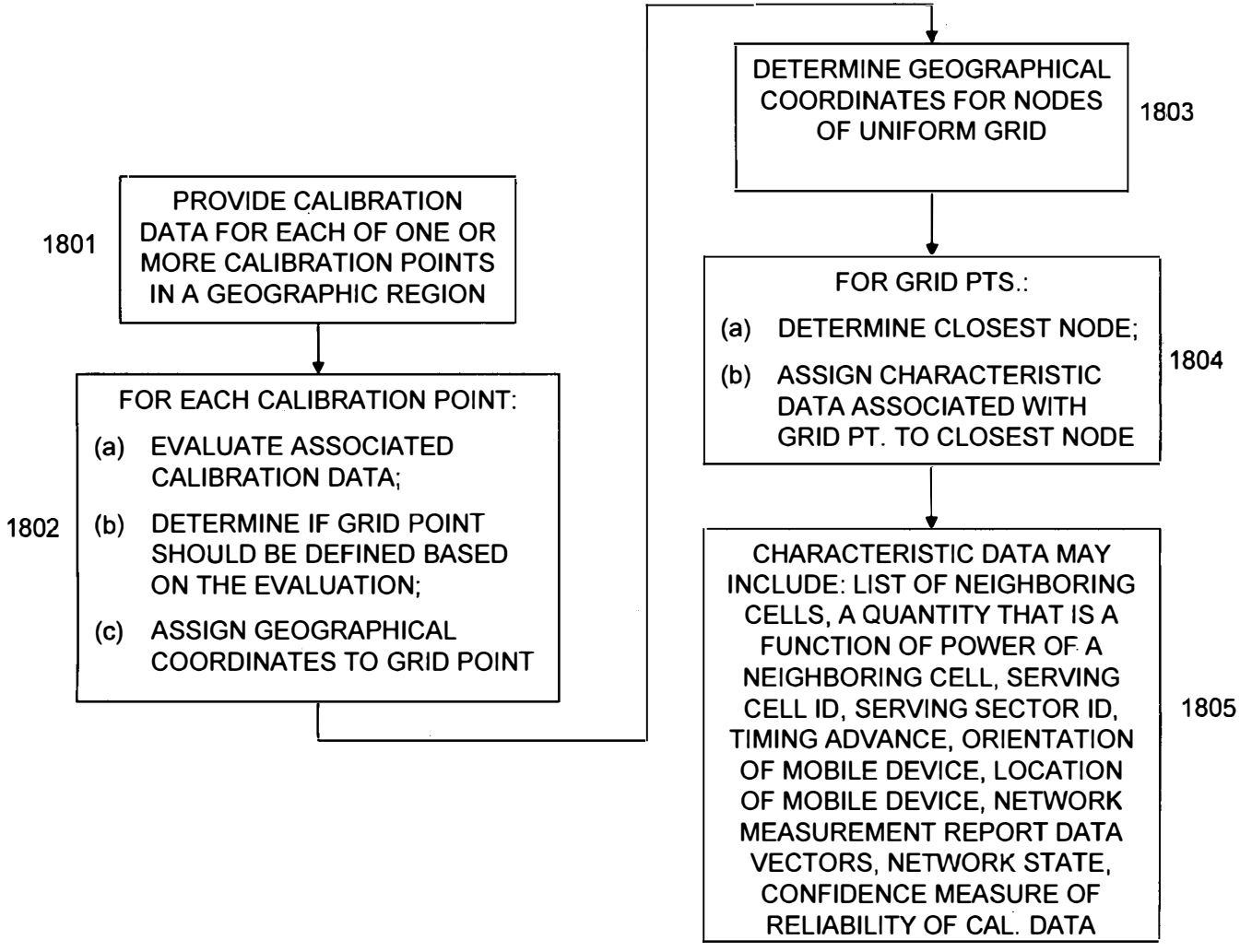
1801
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1802
FOR EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1803
DETERMINE 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

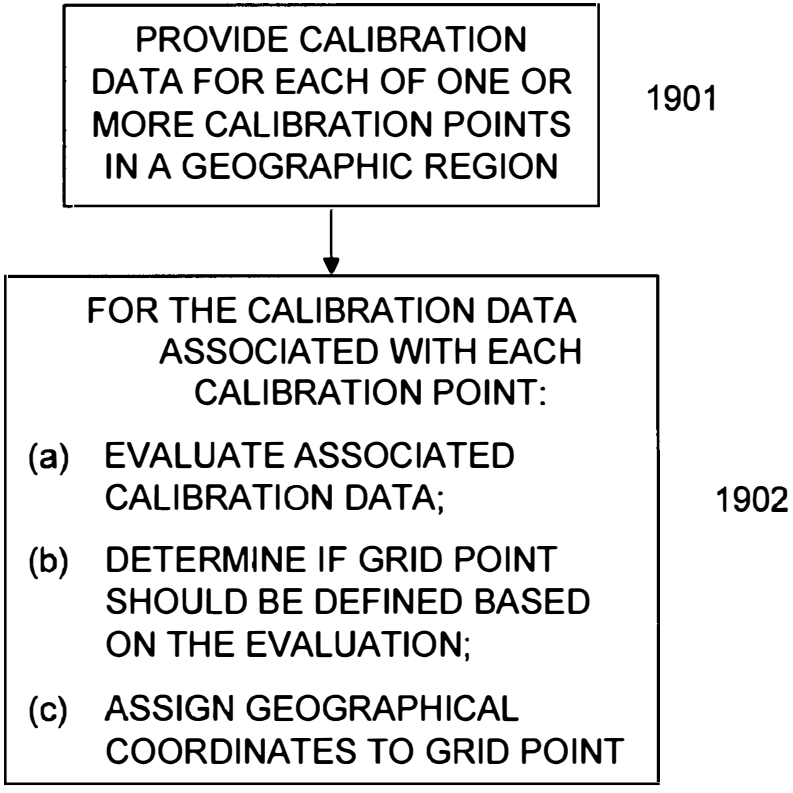
PROVIDE CALIBRATION DATA FOR EACH OF ONE OR MORE CALIBRATION POINTS IN A GEOGRAPHIC REGION
1901
FOR THE CALIBRATION DATA ASSOCIATED WITH EACH CALIBRATION POINT:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
1902

FIGURE 19

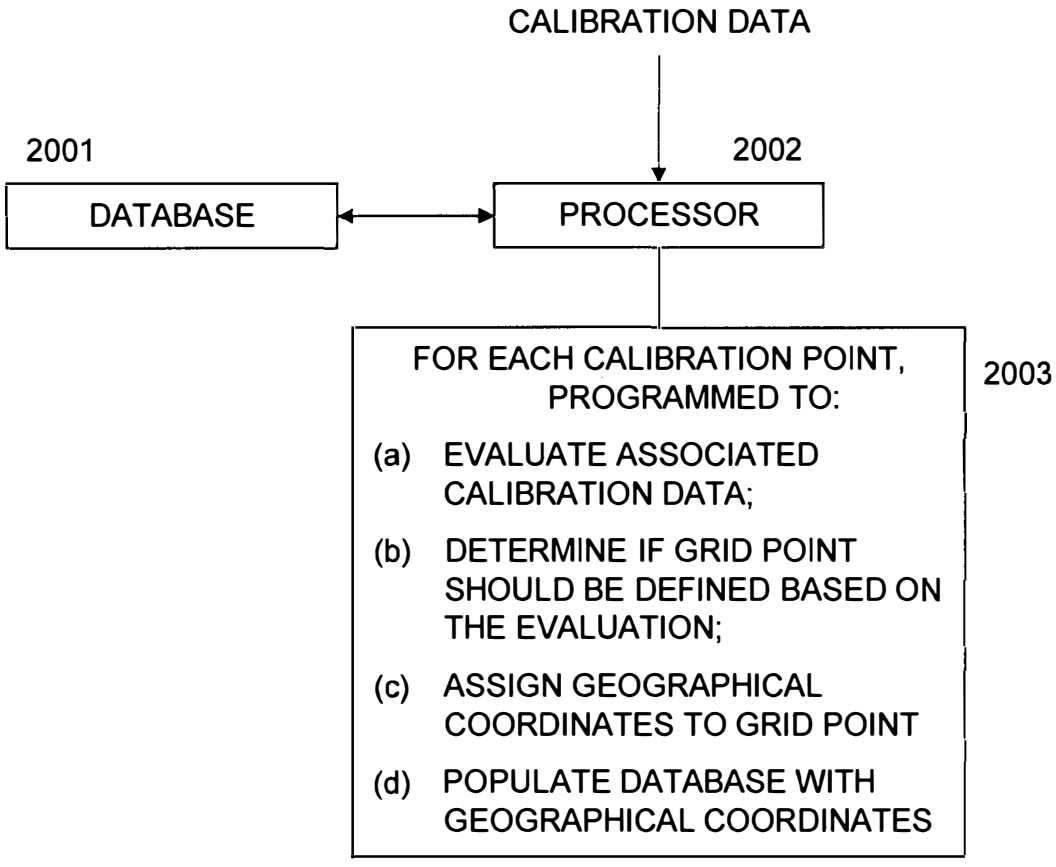
CALIBRATION DATA
2001
DATABASE
2002
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2003

FIGURE 20

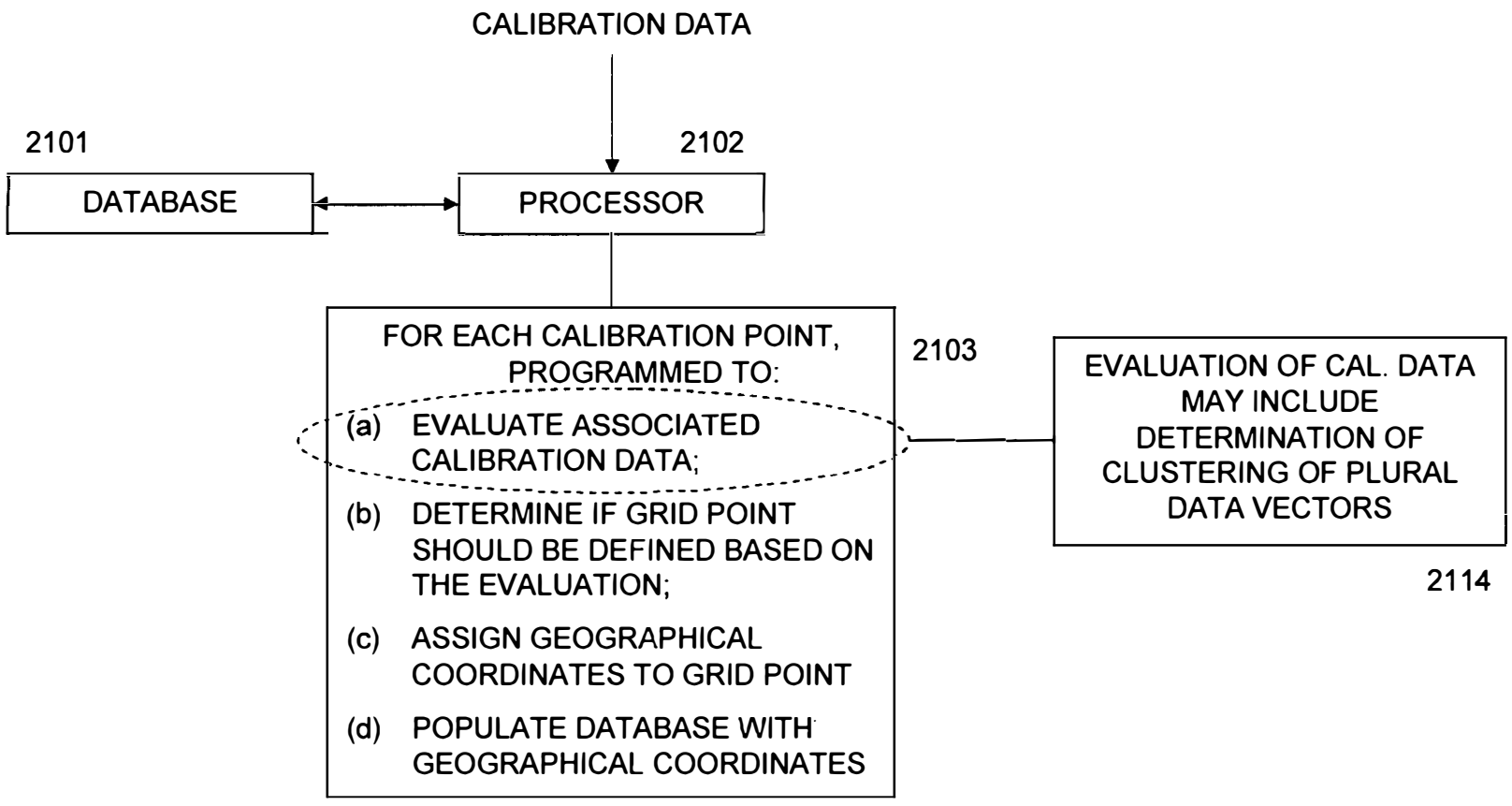
CALIBRATION DATA
2101
DATABASE
2102
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
2103
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
2114

FIGURE 21

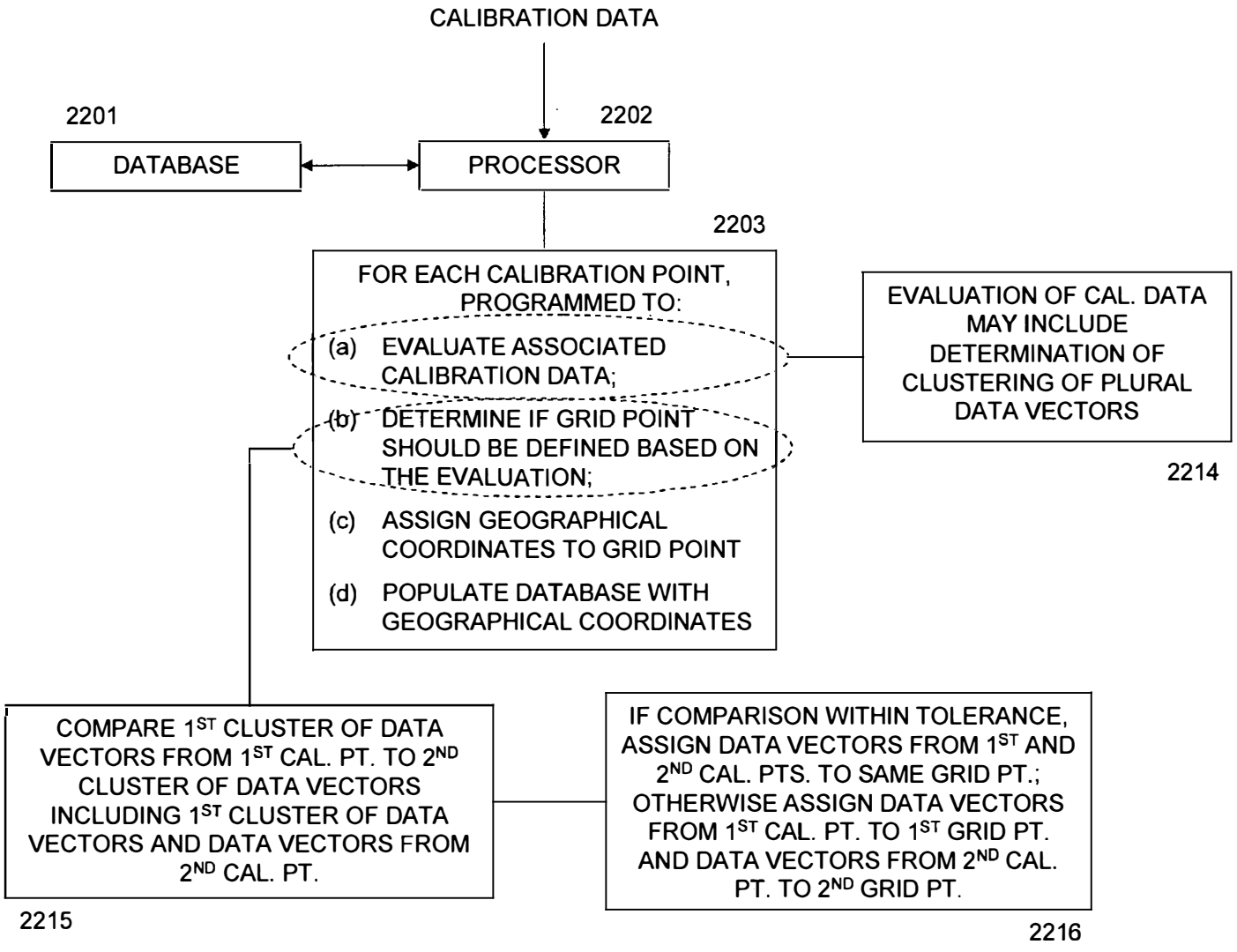
CALIBRATION DATA
2201
DATABASE
2202
PROCESSOR
2203
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
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

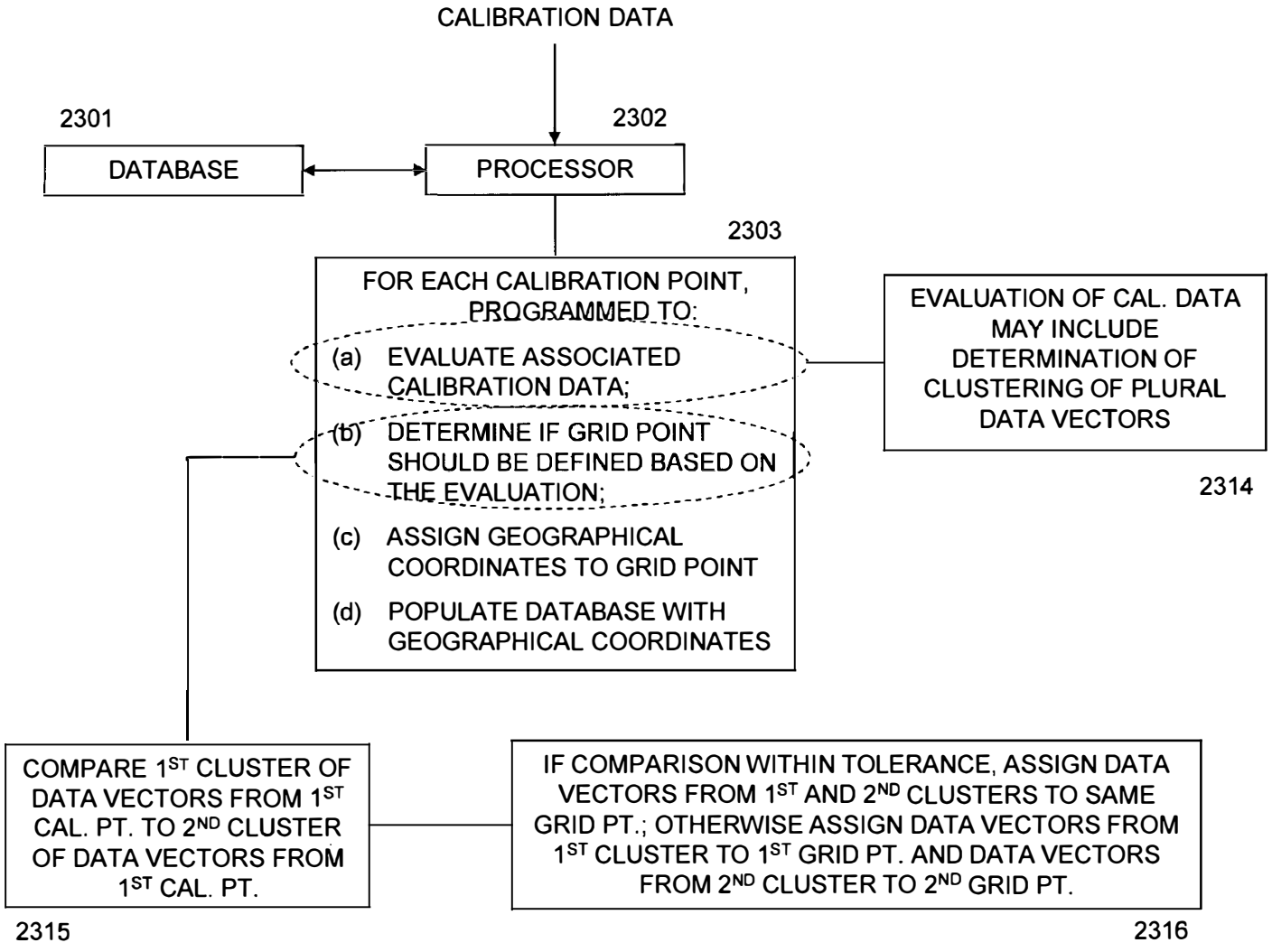
CALIBRATION DATA
2301
DATABASE
2302
PROCESSOR
2303
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
EVALUATION OF CAL. DATA MAY INCLUDE DETERMINATION OF CLUSTERING OF PLURAL DATA VECTORS
2314
COMPARE 1ST CLUSTER OF DATA VECTORS FROM 1ST CAL. PT. TO 2ND CLUSTER OF DATA VECTORS FROM 1ST CAL. PT.
2315
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.
2316

FIGURE 23

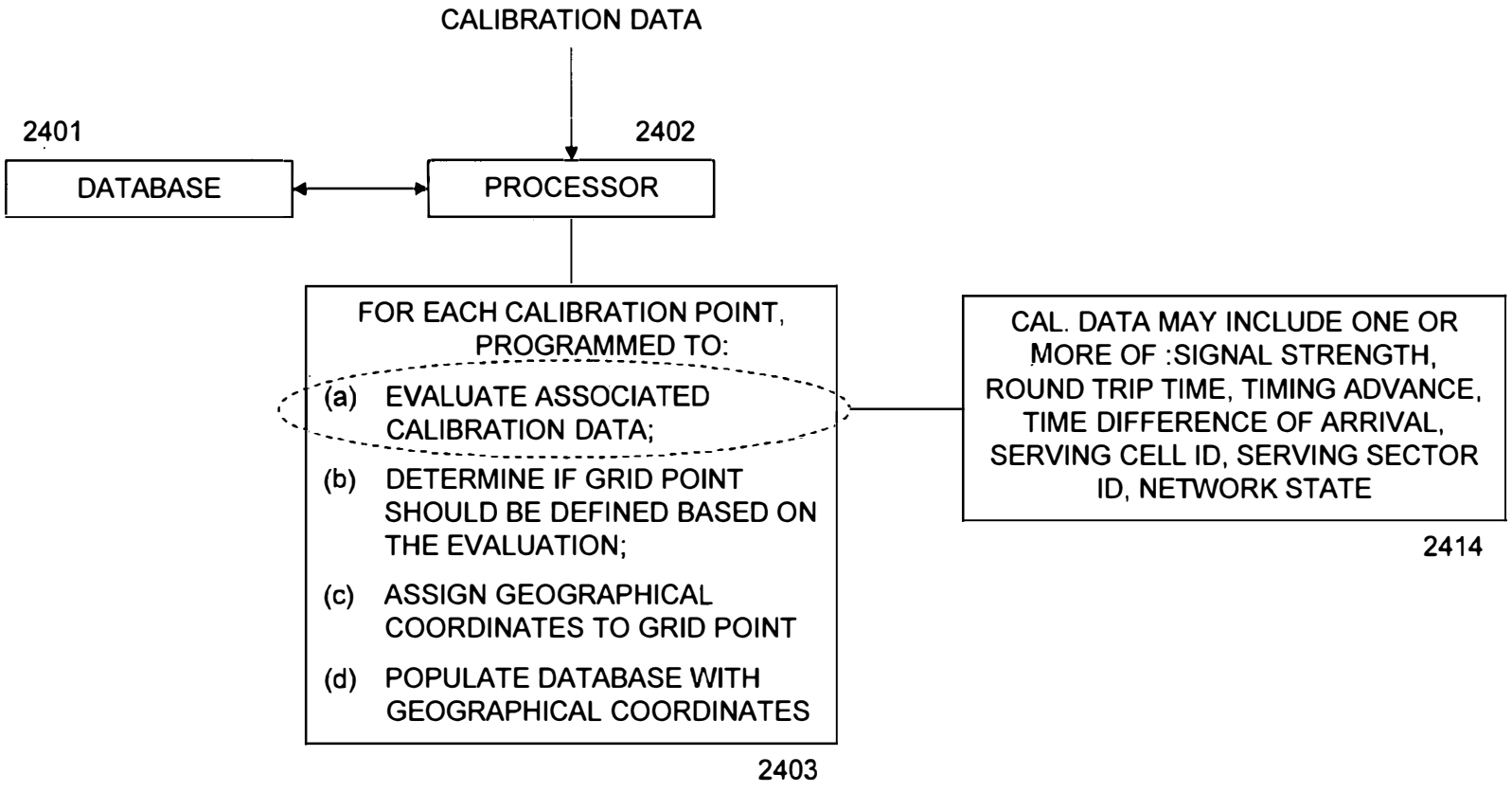
CALIBRATION DATA
2401
DATABASE
2402
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
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

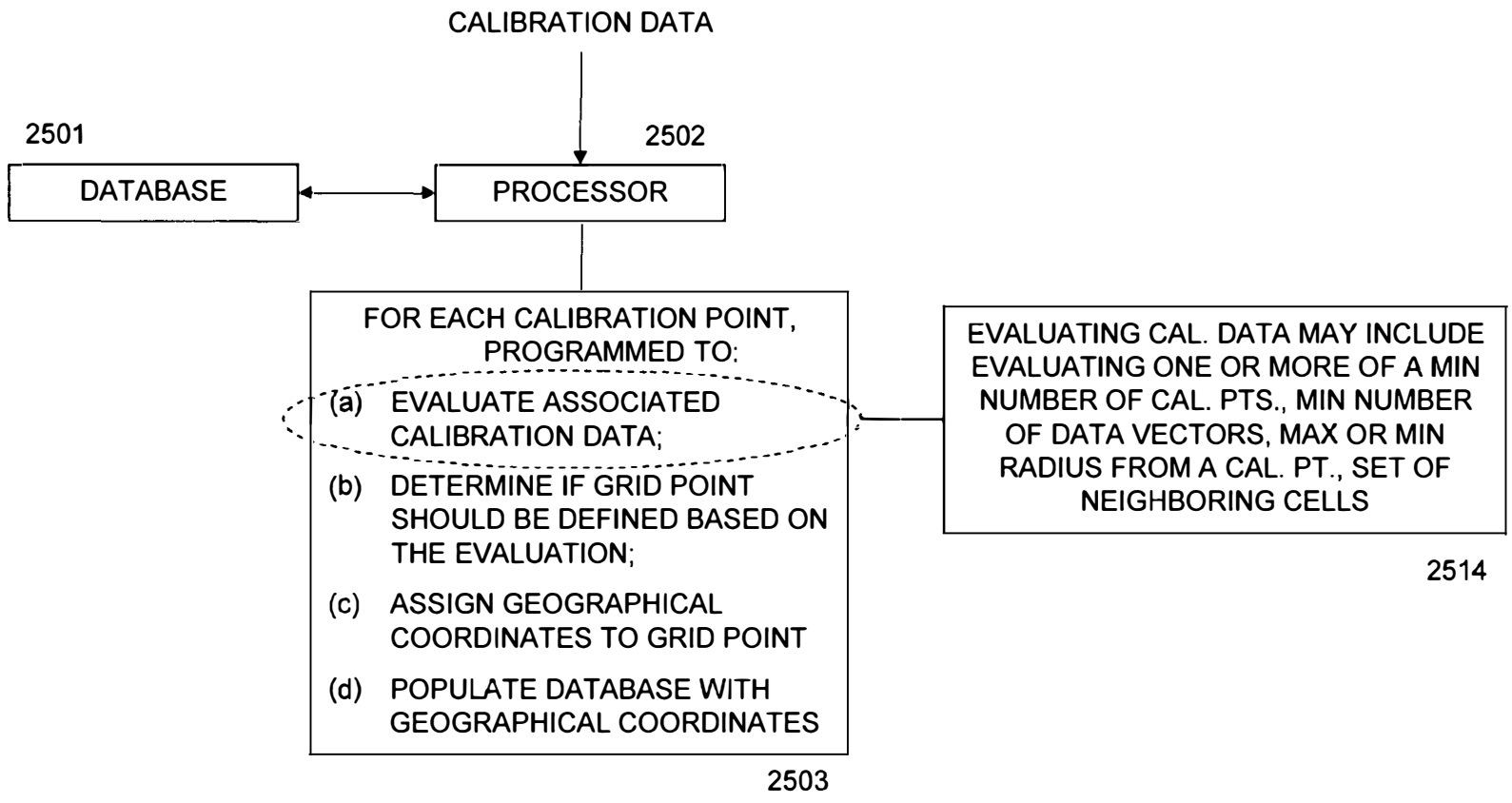
CALIBRATION DATA
2501
DATABASE
2502
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
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

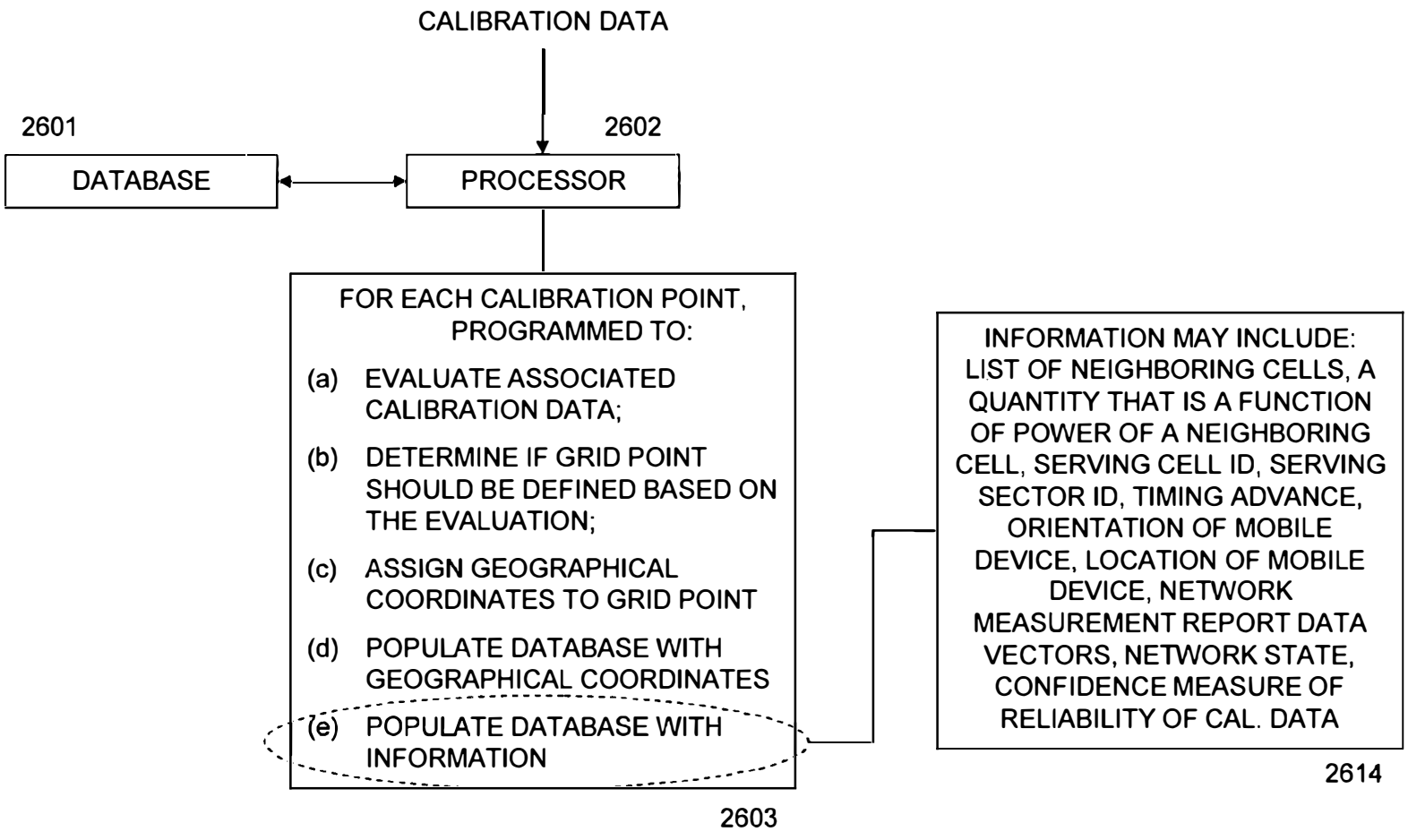
CALIBRATION DATA
2601
DATABASE
2602
PROCESSOR
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(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

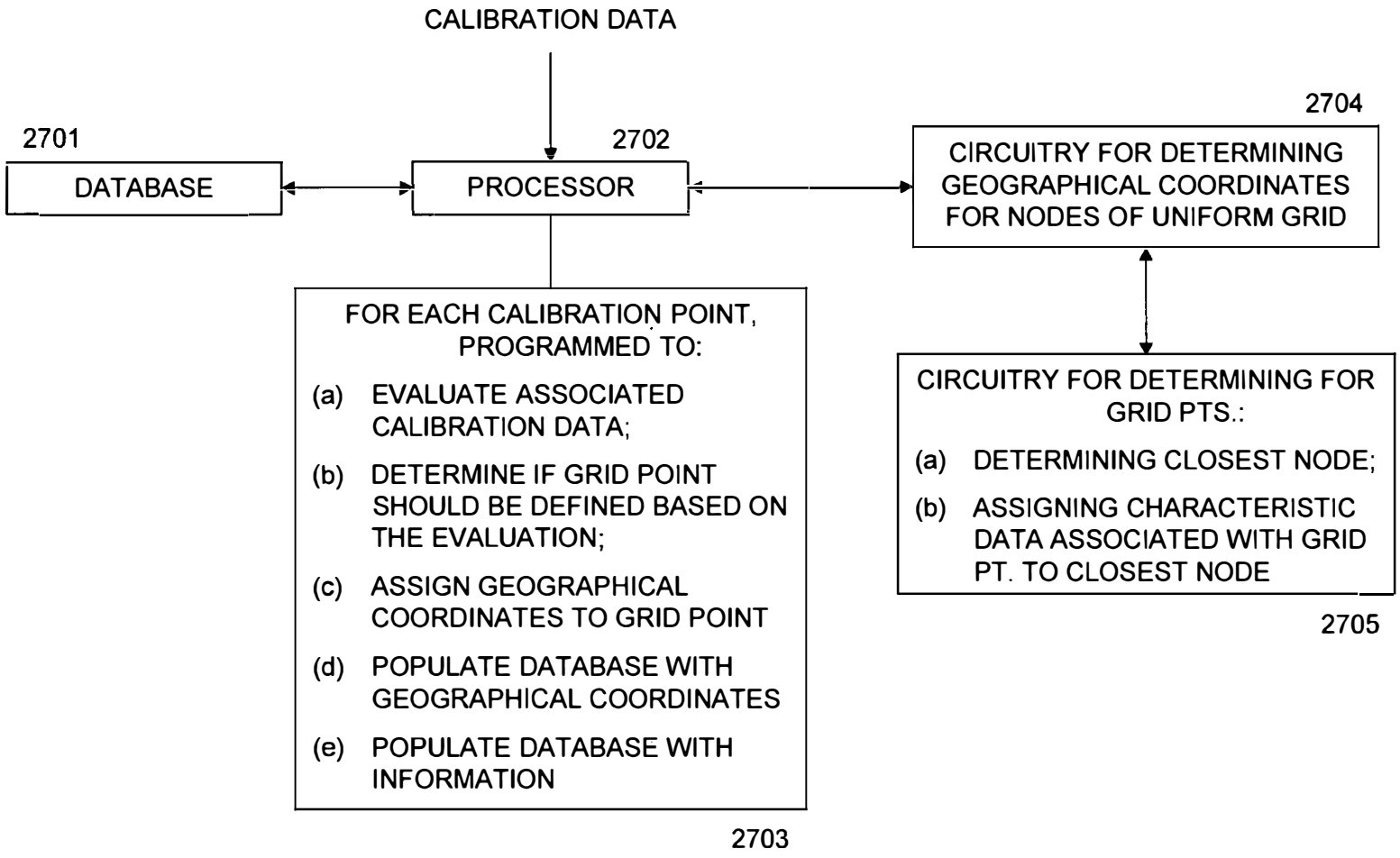
CALIBRATION DATA
2701
DATABASE
2702
PROCESSOR
2704
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2703
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
2705

FIGURE 27

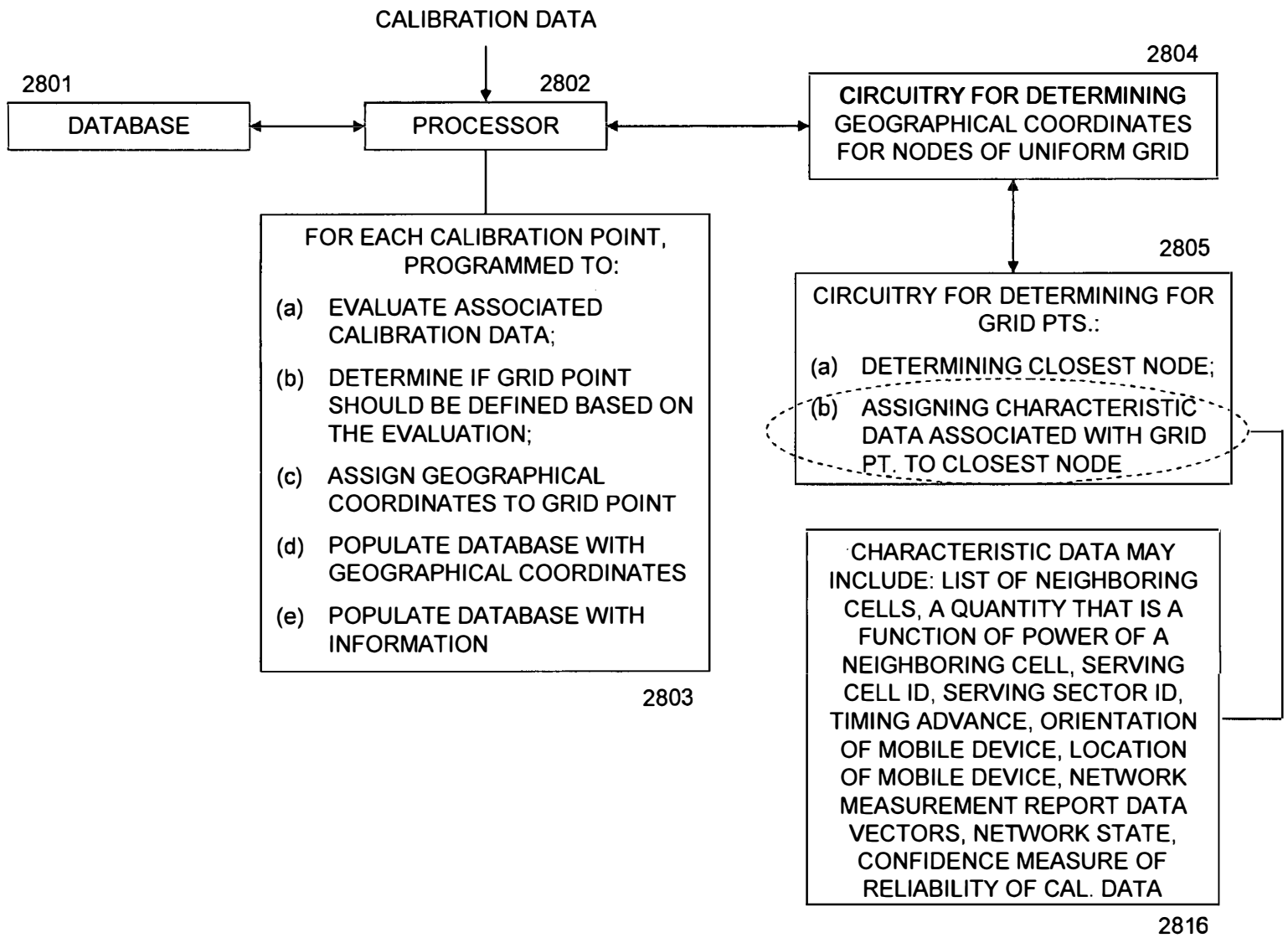
CALIBRATION DATA
2801
DATABASE
2802
PROCESSOR
2804
CIRCUITRY FOR DETERMINING GEOGRAPHICAL COORDINATES FOR NODES OF UNIFORM GRID
FOR EACH CALIBRATION POINT, PROGRAMMED TO:
(a) EVALUATE ASSOCIATED CALIBRATION DATA;
(b) DETERMINE IF GRID POINT SHOULD BE DEFINED BASED ON THE EVALUATION;
(c) ASSIGN GEOGRAPHICAL COORDINATES TO GRID POINT
(d) POPULATE DATABASE WITH GEOGRAPHICAL COORDINATES
(e) POPULATE DATABASE WITH INFORMATION
2803
2805
CIRCUITRY FOR DETERMINING FOR GRID PTS.:
(a) DETERMINING CLOSEST NODE;
(b) ASSIGNING CHARACTERISTIC DATA ASSOCIATED WITH GRID PT. TO CLOSEST NODE
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
2816

FIGURE 28

SYSTEM AND METHOD FOR GENERATING NON-UNIFORM GRID POINTS FROM CALIBRATION DATA

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority benefit to and hereby incorporates by reference in its entirety U.S. Provisional Patent Application Ser. No. 60/899,379 filed on 5 Feb. 2007.

BACKGROUND

The present disclosure 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 disclosure 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 disclosure 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 disclosure 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 disclosure 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 disclosure, 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 disclosure 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.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a flow chart for a method for assigning geographical coordinates according to an embodiment of the disclosure.

FIG. **2** is a flow chart for a method for assigning geographical coordinates including a calibration point according to an embodiment of the disclosure.

FIG. **3** is a flow chart for a method for assigning geographical coordinates including calibration data according to an embodiment of the disclosure.

FIG. **4** is a flow chart for a method for assigning geographical coordinates including clustering of data according to an embodiment of the disclosure.

FIG. **5** is a flow chart for a method for assigning geographical coordinates including clustering of data vectors according to an embodiment of the disclosure.

FIG. **6** is a flow chart for a method for assigning geographical coordinates including clustering according to an embodiment of the disclosure.

FIG. **7** is a flow chart for a method for assigning geographical coordinates including determining outliers according to an embodiment of the disclosure.

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 disclosure.

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 disclosure.

FIG. **10** is a flow chart for a method for assigning geographical coordinates to a grid point according to an embodiment of the disclosure.

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 disclosure.

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 disclosure.

FIG. **13** is a flow chart for a method for assigning geographical coordinates including calibration data information according to an embodiment of the disclosure.

FIG. **14** is a flow chart for a method for assigning geographical coordinates including evaluating calibration data according to an embodiment of the disclosure.

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 disclosure.

FIG. **16** is a flow chart for a method for assigning geographical coordinates including database information according to an embodiment of the disclosure.

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 disclosure.

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 disclosure.

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 disclosure.

FIG. **20** is a block diagram for a system for assigning geographical coordinates according to an embodiment of the disclosure.

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 disclosure.

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 disclosure.

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 disclosure.

FIG. **24** is a block diagram for a system for assigning geographical coordinates including calibration data according to an embodiment of the disclosure.

FIG. **25** is a block diagram for a system for assigning geographical coordinates including evaluating calibration data according to an embodiment of the disclosure.

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 disclosure.

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 disclosure.

FIG. **28** is a block diagram for a system for assigning geographical coordinates including characteristic data according to an embodiment of the disclosure.

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 various embodiments of a system and method for assigning

geographical coordinates to a grid point in a geographic region for the location of a mobile device are herein described.

The present disclosure 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 the data, associated with the various grid points to thereby estimate the location of the mobile.

The system and/or method of the present disclosure 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 disclosure 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 may be termed the NUG characteristics. The NUG characteristics may be a representation that attempts 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 (i.e., 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 disclosure. 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 is it 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 is it 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 disclosure. 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 disclosure. 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 a comparing clusters of data vectors from different calibration points according to an embodiment of the disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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 disclosure. 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.

While preferred embodiments of the present disclosure 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 equivalents, many variations and modifications naturally occurring to those of skill in the art from a perusal hereof.

We claim:

1. A method of assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device, comprising:

(a) providing calibration data for each of one or more calibration points in the geographic region;

(b) for each of said calibration points:

(i) evaluating the associated calibration data;

(ii) determining if at least one grid point should be defined based on said evaluation; and

(iii) assigning geographical coordinates to said at least one grid point,

(c) determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning said geographic region; and

(d) for each of said at least one grid point:

(i) determining a closest node from said plurality of nodes; and

(ii) assigning characteristic data associated with said grid point to said closest node,

wherein for each of select ones of said calibration points the calibration data includes plural data vectors and the evaluating of said calibration data comprises a determination of clustering of said plural data vectors,

and wherein said characteristic data comprises data selected from the group consisting of: a list of cells neighboring a cell serving said mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving said mobile device; an identity of a cell or a sector serving said mobile device; a timing advance parameter; a geographical orientation of said mobile device; a location of said mobile device; network measurement report data vectors; a state of a network serving said mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

2. The method of claim **1** wherein one of said calibration points is located on a predetermined fixed uniform grid defined over said region.

3. The method of claim **1** wherein one of said calibration points is randomly located within said region.

4. The method of claim **1** wherein said calibration data comprises information from a network measurement report.

5. The method of claim **1** wherein said calibration data for one of said calibration points is obtained from one or more mobile devices located in close proximity to said one calibration point.

6. The method of claim **1** wherein said calibration data for one of said calibration points is obtained from a signal transmitted from a mobile device in close proximity to said one calibration point and received at a receiver in or in proximity to said region.

7. The method of claim 1 wherein said determining if at least one grid point should be defined based on said evaluation includes:

(A) comparing a first cluster of data vectors from a first one of said select calibration points to a second cluster of data vectors comprising said first cluster of data vectors and data vectors from a second one of said select calibration points; and

(B) if said comparison is within a predetermined tolerance, assigning said data vectors from said first and said second calibration points to the same grid point, otherwise assigning the data vectors from said first calibration point to a first grid point and assigning the data vectors from said second calibration point to a second grid point.

8. The method of claim 7 wherein said determination of clustering of said plural data vectors includes a K-means algorithm analysis and wherein said comparing of a cluster of data vectors includes determining a probability density function of an aspect of said data vectors.

9. The method of claim 1 further comprising determining outlier data vectors and eliminating said outliers from said determination of clustering.

10. The method of claim 1 wherein said determining if at least one grid point should be defined based on said evaluation includes:

(A) comparing a first cluster of data vectors from a first one of said select calibration points to a second cluster of data vectors from said first one of said select calibration points; and

(B) if said comparison is within a predetermined tolerance, assigning said data vectors from said first and said second clusters to the same grid point, otherwise assigning the data vectors from said first cluster to a first grid point and assigning the data vectors from said second cluster to a second grid point.

11. The method of claim 10 wherein the geographical coordinates assigned to said first and second grid points are identical.

12. The method of claim 1 wherein the geographical coordinates assigned to said at least one grid point are different than the geographical coordinates of any of said calibration points.

13. The method of claim 1 wherein the geographical coordinates assigned to said at least one grid point are the same as the geographical coordinates of one of said calibration points.

14. The method of claim 1 wherein only one calibration point is in said geographic region and the geographical coordinates assigned to said at least one grid point result in said at least one grid point being located within a predetermined radius of said one calibration point.

15. The method of claim 1 wherein only one calibration point is in said geographic region and the geographical coordinates assigned to said at least one grid point are identical to geographic coordinates of said one calibration point.

16. The method of claim 1 wherein plural calibration points are in said geographic region and wherein the geographical coordinates assigned to said at least one grid point result in said at least one grid point being located within a predetermined radius of a geographic centroid determined from geographic coordinates of said plural calibration points.

17. The method of claim 1 wherein said calibration data 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 calibration point; signal strength of a signal transmitted by a transmitter located at said calibration point as received by a receiver at a known location; round trip time for a signal traveling between said calibration point and a known location; timing advance of a signal received by said mobile device at said calibration point; time difference of arrival of plural signals at said calibration point with respect to a pair of known locations as measured by a receiver at said calibration point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said calibration point; a state of a wireless network serving said mobile device, and combinations thereof.

18. The method of claim 1 wherein said evaluating the associated calibration data includes an evaluation selected from the group consisting of: a minimum number of unique neighboring calibration points as determined by calibration data of said neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum radius from said calibration point; a predetermined set of cells neighboring a cell serving said mobile device; and combinations thereof.

19. The method of claim 1 further comprising populating a database with said geographical coordinates.

20. The method of claim 19 further comprising populating said database with information selected from the group consisting of: a list of cells neighboring a cell serving said mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving said mobile device; an identity of a cell or a sector serving said mobile device; a timing advance parameter; a geographical orientation of said mobile device; a location of said mobile device; network measurement report data vectors; a state of a network serving said mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

21. A method of assigning geographical coordinates to a grid point located in a geographic region for the location of a mobile device, comprising:

(a) providing calibration data for each of one or more calibration points in the geographic region;

(b) for the calibration data associated with each of said calibration points:

(i) evaluating the associated calibration data;

(ii) determining if at least one grid point should be defined based on said evaluation; and

(iii) assigning geographical coordinates to said at least one grid point,

(c) determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning said geographic region; and

(d) for each of said at least one grid point:

(i) determining a closest node from said plurality of nodes; and

(ii) assigning characteristic data associated with said grid point to said closest node,

wherein for each of select ones of said calibration points the calibration data includes plural data vectors and the evaluating of said calibration data comprises a determination of clustering of said plural data vectors,

and wherein said characteristic data comprises data selected from the group consisting of: a list of cells neighboring a cell serving said mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving said mobile device; an identity of a cell or a sector serving said mobile device; a timing advance parameter; a geographical orientation of said mobile device; a location of said mobile device; network measurement report data vectors; a state of a network serving said mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

22. A system for assigning geographical coordinates to a grid point located in a geographic region, comprising:

a database; and

a processor for receiving calibration data for each of one or more calibration points in said geographic region and for each of said calibration points said processor is programmed to:

evaluate the associated calibration data;

determine if at least one grid point should be defined based on said evaluation;

assign geographical coordinates to said at least one grid point; and

populate said database with said geographical coordinates,

said processor further programmed to:

determine geographical coordinates for each of a plurality of nodes of a uniform grid spanning said geographic region; and

for each of said at least one grid point, determining a closest node from said plurality of nodes; and assigning characteristic data associated with said grid point to said closest node,

wherein for each of select ones of said calibration points the calibration data includes plural data vectors and the evaluating of said calibration data comprises a determination of clustering of said plural data vectors,

and wherein said characteristic data comprises data selected from the group consisting of: a list of cells neighboring a cell serving said mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving said mobile device; an identity of a cell or a sector serving said mobile device; a timing advance parameter; a geographical orientation of said mobile device; a location of said mobile device; network measurement resort data vectors; a state of a network serving said mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

23. The system of claim 22 wherein one of said calibration points is located on a predetermined fixed uniform grid defined over said region.

24. The system of claim 22 wherein one of said calibration points is randomly located within said region.

25. The system of claim 22 wherein said calibration data comprises information from a network measurement report.

26. The system of claim 22 wherein said calibration data for one of said calibration points is obtained from one or more mobile devices located in close proximity to said one calibration point.

27. The system of claim 22 wherein said calibration data for one of said calibration points is obtained from a signal transmitted from a mobile device in close proximity to said one calibration point and received at a receiver in or in proximity to said region.

28. The system of claim 22 wherein said determining if at least one grid point should be defined based on said evaluation includes:

(A) comparing a first cluster of data vectors from a first one of said select calibration points to a second cluster of data vectors comprising said first cluster of data vectors and data vectors from a second one of said select calibration points; and

(B) if said comparison is within a predetermined tolerance, assigning said data vectors from said first and said second calibration points to the same grid point, otherwise assigning the data vectors from said first calibration point to a first grid point and assigning the data vectors from said second calibration point to a second grid point.

29. The system of claim 28 wherein said determination of clustering of said plural data vectors includes a K-means algorithm analysis and wherein said comparing of a cluster of data vectors includes determining a probability density function of an aspect of said data vectors.

30. The system of claim 22 wherein said processor is further programmed to determine outlier data vectors and eliminating said outliers from said determination of clustering.

31. The system of claim 22 wherein said determining if at least one grid point should be defined based on said evaluation includes:

(A) comparing a first cluster of data vectors from a first one of said select calibration points to a second cluster of data vectors from said first one of said select calibration points; and

(B) if said comparison is within a predetermined tolerance, assigning said data vectors from said first and said second clusters to the same grid point, otherwise assigning the data vectors from said first cluster to a first grid point and assigning the data vectors from said second cluster to a second grid point.

32. The system of claim 31 wherein the geographical coordinates assigned to said first and second grid points are identical.

33. The system of claim 22 wherein the geographical coordinates assigned to said at least one grid point are different than the geographical coordinates of any of said calibration points.

34. The system of claim 22 wherein the geographical coordinates assigned to said at least one grid point are the same as the geographical coordinates of one of said calibration points.

35. The system of claim 22 wherein only one calibration point is in said geographic region and the geographical coordinates assigned to said at least one grid point result in said at least one grid point being located within a predetermined radius of said one calibration point.

36. The system of claim 22 wherein only one calibration point is in said geographic region and the geographical coordinates assigned to said at least one grid point are identical to geographic coordinates of said one calibration point.

37. The system of claim 22 wherein plural calibration points are in said geographic region and wherein the geographical coordinates assigned to said at least one grid point result in said at least one grid point being located within a predetermined radius of a geographic centroid determined from geographic coordinates of said plural calibration points.

38. The system of claim 22 wherein said calibration data 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 calibration point; signal strength of a signal transmitted by a transmitter located at said calibration point as received by a receiver at a known location; round trip time for a signal traveling between said calibration point and a known location; timing advance of a signal received by said mobile device at said calibration point; time difference of arrival of plural signals at said calibration point with respect to a pair of known locations as measured by a receiver at said calibration point or at said known locations; the identification of a serving cell or serving sector of said mobile device located at said calibration point; a state of a wireless network serving said mobile device, and combinations thereof.

39. The system of claim 22 wherein said evaluating the associated calibration data includes an evaluation selected from the group consisting of: a minimum number of unique

neighboring calibration points as determined by calibration data of said neighboring calibration points; a minimum number of data vectors or network measurement reports; a predetermined maximum or minimum radius from said calibration point; a predetermined set of cells neighboring a cell serving said mobile device; and combinations thereof.

40. The system of claim **22** wherein said processor is further programmed to populate said database with information selected from the group consisting of: a list of cells neighboring a cell serving said mobile device; a quantity that is a function of a power level of one or more cells neighboring a cell serving said mobile device; an identity of a cell or a sector serving said mobile device; a timing advance parameter; a geographical orientation of said mobile device; a location of said mobile device; network measurement report data vectors; a state of a network serving said mobile device; a confidence measure indicative of a reliability of the calibration data; and combinations thereof.

41. The system of claim **22** further comprising:

circuitry for determining geographical coordinates for each of a plurality of nodes of a uniform grid spanning said geographic region; and

circuitry for determining, for each of said at least one grid point, a closest node from said plurality of nodes and assigning characteristic data associated with said grid point to said closest node.

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