

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Martin Alles et al.
U.S. Patent No.: 8,786,494 Attorney Docket No.: 50095-0139IP1
Issue Date: July 22, 2014
Appl. Serial No.: 13/771,542
Filing Date: February 20, 2013
Title: METHOD TO MODIFY CALIBRATION DATA USED TO
LOCATE A MOBILE UNIT

DECLARATION OF DR. KARTHIKEYAN SUNDARESAN

I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of the Title 18 of the United States Code.

Dated: 10/01/2023

By: _____

Karthikeyan Sundaresan, Ph.D.

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I, Karthikeyan Sundaresan of Atlanta, GA, declare that:

I. ASSIGNMENT

1. I have been retained on behalf of Apple Inc. (“Apple”) to offer technical opinions related to U.S. Patent No 8,786,494 (“the ’494 patent”) (APPLE-1001). I understand that Apple is requesting that the Patent Trial and Appeal Board (“PTAB” or “Board”) to institute an *inter partes* review (“IPR”) proceeding of the ’494 patent.

2. I have been asked to provide my independent analysis of the ’494 patent based on the prior art publications cited in this declaration.

3. I am not and never have been, an employee of Apple. I received no compensation for this declaration beyond my normal hourly compensation based on my time actually spent analyzing the ’494 patent, the prior art publications cited below, and issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the ’494 patent.

II. QUALIFICATIONS

4. I am over the age of 18 and am competent to write this declaration. I have personal knowledge, or have developed knowledge of these technologies based upon education, training, or experience, of the matters set forth herein.

5. I am a Professor in the School of ECE, Georgia Tech. Prior to that, I spent fifteen years in wireless and telecom research at NEC Labs America,

Princeton. My research interests are broadly in wireless networking and mobile computing, and span both algorithm design as well as system prototyping. I am the recipient of ACM Sigmobile's Rockstar award (2016) for my contributions to mobile computing and wireless networking, as well as several best paper awards at prestigious ACM and IEEE conferences. I hold over sixty patents, and received a business contribution award for bringing research technology to commercialization at NEC. I also led the spin-out effort of an innovative, lab-grown research technology (NavigateIO Inc.) for infrastructure-free tracking of first responders in GPS-denied environments. I have participated in various organizational and editorial roles for IEEE and ACM conferences and journals, and served as the program committee co-chair for ACM MobiCom'16. I am a Fellow of the IEEE and an ACM distinguished member.

6. My curriculum vitae, attached as Exhibit A, includes a list of publications on which I am a named author. It contains further details regarding my experience, education, publications, and other qualifications provide to an expert opinion in connection with this proceeding.

III. SUMMARY OF CONCLUSIONS FORMED

7. This Declaration explains the conclusions that I have formed based on my analysis. To summarize those conclusions:

- **Ground 1A:** Based upon my knowledge and experience and my review of the prior art publications in this declaration, claims 1, 2, 5, 9, 12, 14, 16, and 18-22 of the '494 patent are anticipated by Bhattacharya.
- **Ground 1B:** Based upon my knowledge and experience and my review of the prior art publications in this declaration, claims 1-5, 9, 11, 12, 14-16, and 18-22 of the '494 patent are made obvious by Bhattacharya and Spain.
- **Ground 1C:** Based upon my knowledge and experience and my review of the prior art publications in this declaration, claims 25, 27, 29, 31, 32, and 35 of the '494 patent are made obvious by Bhattacharya and Meunier.
- **Ground 1D:** Based upon my knowledge and experience and my review of the prior art publications in this declaration, claims 25, 27, 29, 31, 32, and 35 of the '494 patent are made obvious by Bhattacharya, Spain, and Meunier.

IV. LEVEL OF ORDINARY SKILL IN THE ART

8. I have been informed that a person of ordinary skill in the art ("POSITA") had at least a Bachelor's degree in electrical engineering, computer science, or a similar discipline, and at least two years of experience in the field

working with navigation and/or geolocation systems. Superior education could compensate for a deficiency in work experience, and *vice-versa*.

Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, mentored, advised, and collaborated closely with many such individuals over the course of my career.

V. LEGAL PRINCIPLES

9. I am not a lawyer and I will not provide any legal opinions in this IPR. Although not a lawyer, I have been advised that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims.

A. Claim Interpretation

10. I understand that claim terms are generally given their plain and ordinary meaning based on the patent's specification and file history as understood by a person of ordinary skill in the art at the time of the purported invention. In that regard, I understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by a POSITA. I further understand that the words of the claims should be given their plain meaning unless that meaning is inconsistent with the patent specification or the patent's history of examination before the Patent Office. I also understand that the words of the

claims should be interpreted as they would have been interpreted by a POSITA at the time the invention was made (not today).

B. Priority

11. I understand that a continuation application is a later-filed application that has the same disclosure (specification and figures) as an earlier filed application to which the later-filed application claims priority. A continuation is generally entitled to the same priority date as the earlier-filed application to which it claims priority.

C. Anticipation

12. I understand that a patent claim is invalid as anticipated if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference. I also understand that, to anticipate, the reference must teach all of the limitations arranged or combined in the same way as described in the claim. I do not rely on anticipation in this declaration.

13. With respect to inherency, I understand that the fact that a certain result or characteristic may occur or be present in the prior art is not sufficient to establish the inherency of that result or characteristic. Instead, the inherent characteristic must necessarily flow from the teaching of the prior art.

D. Obviousness

14. I understand that a patent claim is invalid if the claimed invention would have been obvious to a person of ordinary skill in the field at the time of the purported invention, which is often considered the time the application was filed. Even if all of the claim limitations are not found in a single prior art reference that anticipates the claim, the claim can still be invalid.

15. To obtain a patent, a claimed invention must have, as of the priority date, been nonobvious in view of the prior art in the field. I understand that an invention is obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art.

16. I understand that, to prove that prior art or a combination of prior art makes a patent obvious it is necessary to: (1) identify the particular references that, singly or in combination, make the patent obvious; (2) specifically identify which elements of the patent claim appear in each of the asserted references; and (3) explain a motivation, teaching, need, market pressure or other legitimate reason that would have inspired a person of ordinary skill in the art to combine prior art references to solve a problem.

17. I also understand that certain objective indicia can be important evidence regarding whether a patent is obvious or nonobvious. Such indicia of non-obviousness include:

- Commercial success of products covered by the patent claims;
- A long-felt need for the invention;
- Failed attempts by others to make the invention;
- Copying of the invention by others in the field;
- Unexpected results achieved by the invention as compared to the closest prior art;
- Praise of the invention by the infringer or others in the field;
- The taking of licenses under the patent by others;
- Expressions of surprise by experts and those skilled in the art at the making of the invention; and
- The patentee proceeded contrary to the accepted wisdom of the prior art.

18. To the extent these factors have been brought to my attention, if at all, I have taken them into consideration in providing my opinions and conclusions.

VI. MATERIALS CONSIDERED

19. My analysis and conclusions set forth in this declaration are based on my educational background and experiences in the field (*see* Section II). Based on

my knowledge and experience, I believe that I am considered to be an expert in the field. Also, based on my knowledge and experience, I understand and know of the capabilities of persons of ordinary skill in the field during the early 2000s–2010s, and I taught, participated in organizations, and worked closely with many such persons in the field during that time frame.

20. As part of my independent analysis for this declaration, I have considered the following: the background knowledge/technologies that were commonly known to persons of ordinary skill in this art during the time before the earliest claimed priority date for the '494 patent; my own knowledge and experiences gained from my work experience in the field of the '494 patent and related disciplines; and my experience in working with others involved in this field and related disciplines.

In addition, I have analyzed the following publications and materials:

- U.S. Patent No. 8,786,494 to Alles et al. (“the '494 patent”) (APPLE-1001)
- Excerpts from the Prosecution History of the '494 Patent (“the Prosecution History”) (APPLE-1002)
- Complaint, *Geoscope Technologies PTE. LTD. v. Apple Inc.*, 1-22-cv-01373 (E.D. Va.), Dec. 1, 2022 (APPLE-1004)

- U.S. Pat. App. Pub. No. 2006/0211376 (“Bhattacharya”) (APPLE-1005)
- U.S. Pat. App. Pub. No. 2006/0240843 (“Spain”) (APPLE-1006)
- U.S. Pat. App. Pub. No. 2005/0130677 (“Meunier”) (APPLE-1007)
- U.S. Pat. No. 6,799,047 (“Bahl”) (APPLE-1008)
- U.S. Patent No. 7,783,299 (“Anderson”) (APPLE-1009)
- Special Mobile Group (SMG) Technical Committee (TC),
European Telecommunications Standards Institute, *GSM Technical Specification - Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification (GSM 04.08)*
(Dec. 1995) (APPLE-1010)
- U.S. Patent No. 6,560,442 (“Yost”) (APPLE-1011)
- Nico Deblauwe, “GSM-based Positioning: Techniques and Applications, 2008, IBSN: 9789054874942 (“Deblauwe”) (APPLE-1012)
- Memorandum Opinion & Order, *Geoscope Technologies PTE. LTD. v Apple Inc.*, 1:22-cv-01373, (E.D. VA. Jul. 19, 2023) (APPLE-1054)

- Stipulation Regarding Agreed Upon Claim Constructions,
Geoscope Technologies PTE. LTD. v Apple Inc., 1:22-cv-01373,
(E.D. VA. May 23, 2023) (APPLE-1052)

21. My analysis and conclusions set forth in this declaration are based on the perspective of a POSITA.

VII. OVERVIEW OF THE '494 PATENT

A. Specification

22. The '494 patent is directed to a “method to modify calibration data used to locate a mobile unit.” APPLE-1001, Title. The '494 patent generally relates to determining the location of a “mobile station” (e.g., a mobile device like a cell phone) by comparing previously collected “calibration data” in a cellular network for a known or defined location with network measurement data observed at an unknown location. *Id.*, Abstract. “Calibration data” can be collected in advance for a geographic region, e.g., by driving around the known or defined locations. *Id.*, 1:65-2:6; 10:55-58. When a mobile device observes network measurement data from an unknown location, that observed data can be compared (or “matched”) to the “calibration data” to estimate the device’s location. *Id.*, 1:50-54, 7:1-6.

B. Claims

23. The table below includes identifiers for the '494 patent claims and limitations, which are referenced throughout.

Claim	Identifier	Claim Language
1	[1.1]	A method for determining a location of a mobile station, comprising:
	[1.2]	providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
	[1.3]	collecting observed network measurement data;
	[1.4]	the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
	[1.5]	modifying said observed network measurement data; and
	[1.6]	comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.
2	[2]	The method of claim 1 wherein said database comprises previously-gathered calibration data at one or more predetermined calibration points within said region.
3	[3]	The method of claim 2 wherein said previously-gathered calibration data at one or more predetermined calibration points is combined to form previously-gathered calibration data for one or more non-uniform grid points within said region.
4	[4]	The method of claim 1 wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.
5	[5]	The method of claim 1 wherein said previously-gathered calibration data includes signal strength information measured at a predetermined calibration point within said region for a signal transmitted from a known

Claim	Identifier	Claim Language
		location within or in proximity to said region.
9	[9]	The method of claim 1 wherein said previously-gathered calibration data includes information identifying a serving cell of a transmitter transmitting a signal received at a predetermined calibration point within said region.
11	[11]	The method of claim 1 wherein said previously-gathered calibration data includes information regarding a state of said wireless network.
12	[12]	The method of claim 1 wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.
14	[14.1]	A method for determining a location of a mobile station, comprising:
	[14.2]	providing a database of previously-gathered calibration data for a predetermined region in a wireless network,
	[14.3]	wherein said network includes a serving transmitter;
	[14.4]	collecting observed network measurement data including a first signal characteristic from said serving transmitter,
	[14.5]	the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;
	[14.6]	modifying said observed network measurement data using said first signal characteristic; and
	[14.7]	comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.
15	[15]	The method of claim 14 wherein said database comprises previously-gathered calibration data for one or more non-uniform grid points within said region.

Claim	Identifier	Claim Language
16	[16]	The method of claim 14 wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.
18	[18]	The method of claim 14 wherein said first signal characteristic is signal strength.
19	[19]	The method of claim 18 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.
20	[20]	The method of claim 19 wherein the modifying of said calibration data uses a difference between said first and second signal characteristics.
21	[21]	The method of claim 14 wherein said first signal characteristic is signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.
22	[22]	The method of claim 21 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.
25	[25.1]	A method for determining a location of a mobile station, comprising:
	[25.2]	providing a database of previously-gathered calibration data for a predetermined region in a wireless network;
	[25.3]	collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters,
	[25.4]	the observed network measurement data collected by the

Claim	Identifier	Claim Language
		mobile station and transmitted to the network or collected by the network;
	[25.5]	determining an average value for select ones of said signal characteristics;
	[25.6]	modifying said observed network measurement data using said average value; and
	[25.7]	comparing said modified network measurement data with said database of calibration data to thereby determine the location of the mobile station.
27	[27]	The method of claim 25 wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within said region wherein said predetermined calibration point is not located within a structure.
29	[29]	The method of claim 25 wherein said signal characteristic is signal strength.
31	[31]	The method of claim 25 wherein said signal characteristic is signal strength of a control channel.
32	[32]	The method of claim 25, wherein the observed network measurement data includes received signal strength of said transmitters as said mobile station.
35	[35]	The method of claim 25 wherein at least one of said plurality of transmitters is not a member of said wireless network.

C. Prosecution History

24. The '494 patent issued without any substantive prior art rejections cited by the Office as the single Office Action issued in examination asserted only non-statutory double patenting rejections. APPLE-1002, 39-44. The Notice of

Allowance also did not include any Examiner's Statement of Reasons for Allowance. *Id.*, 7-17.

VIII. INTERPRETATION OF THE '494 PATENT CLAIMS

25. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in a patent claim should be interpreted according to their "ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent." 37 C.F.R. § 42.100(b). In that regard, I understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by a POSITA. I further understand that the words of the claims should be given their plain meaning unless that meaning is inconsistent with the patent specification or the patent's history of examination before the Patent Office. I also understand that the words of the claims should be interpreted as they would have been interpreted by a POSITA at the time the invention was made (not today). I was informed by counsel at Fish & Richardson to use the Critical Date (2/5/2007) of the '494 patent as the point in time for claim interpretation purposes. My opinion does not change if the invention date is earlier.

26. I understand that a claim construction order has been issued in a related district court proceeding involving the '358 patent on July 19, 2023.

APPLE-1054. The Court issued constructions for the following terms recited in the Challenged Claims:

Claim Term	Court's Construction
"calibration data"	"modified or unmodified network measurement data associated with a geographic location"
"observed network measurement data"	"measurement data from a network measurement report (i.e., a report used in cellular networks which provides the results of a measurement from a mobile device on one or more cells)"
"grid point"	"a point associated with representative calibration data for an area"

27. It is also my understanding that both parties jointly stipulated that the "collecting" (feature [1.3]) has to occur before the "modifying" (feature [1.5]), and that the modifying has to occur before the "comparing" (feature [1.6]). APPLE-1055, 1.

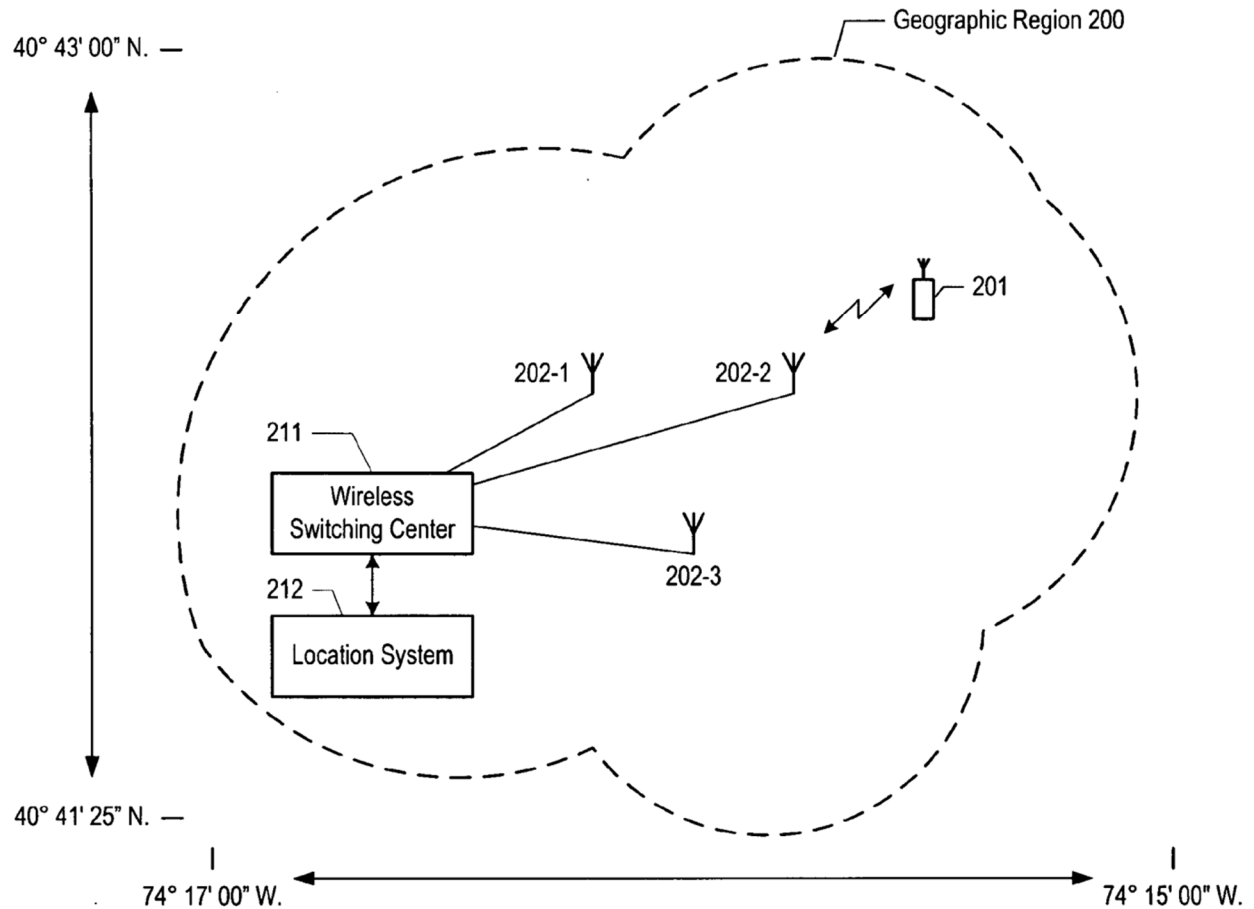
28. The applied prior art references disclose and/or render obvious all of the elements of the challenged claims under any of the above-noted constructions, as discussed in Sections X and XI.

IX. SUMMARY OF RELEVANT PRIOR ART

A. Bhattacharya

29. Bhattacharya is focused on estimating the location of a wireless terminal. APPLE-1005, Abstract. Like the '494 patent, Bhattacharya notes that “[t]here are a variety of reasons why a remote party might be interested in knowing the location of the user,” including for dispatching emergency services (e.g., for a 911 emergency call). APPLE-1005, [0007]; APPLE-1001, 1:20-3:20. And like the location estimation techniques described in the '494 patent. Bhattacharya's location estimation is generally based on comparing (e.g., pattern matching) observed data representing signal strength measurements by the wireless terminal for signals transmitted from nearby base stations and expected values for measured data. *Id.*, [0013]; APPLE-1001, 10:63-11:17. In the Bhattacharya system, a location system receives observed data from the wireless terminal, modifies that data, and compares the modified data against a database that correlates locations to signal strengths to estimate a location of the wireless terminal. *Id.*

30. Figure 2 (below) shows an example of the Bhattacharya system:

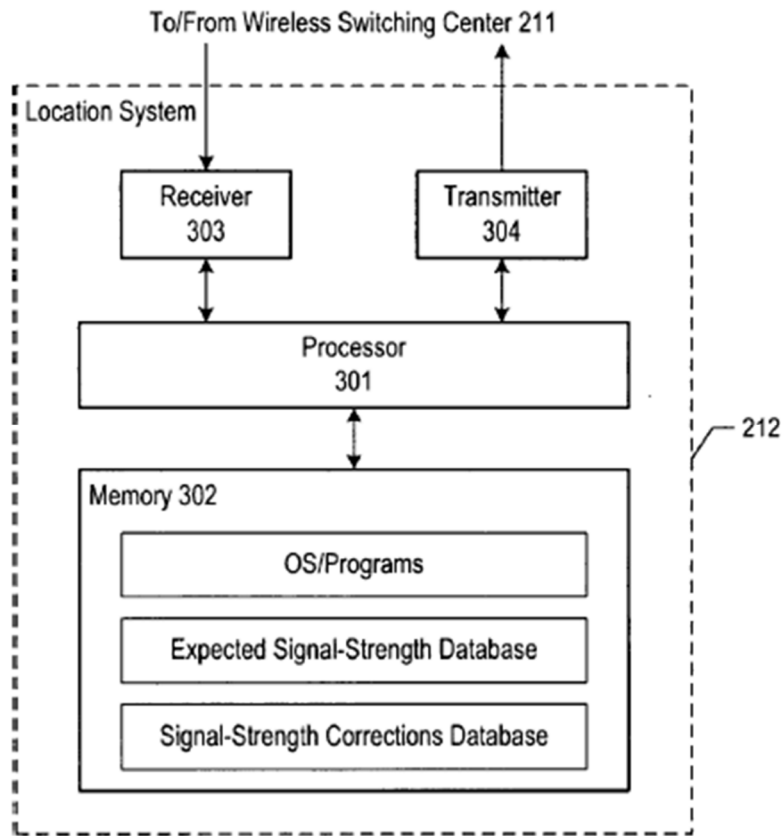


31. As shown above, telecommunications service is provided in geographic region 200 through base stations 202-1, 202-2, 202-3 and wireless terminal 201 through several well-known mobile communication protocols. APPLE-1005, [0051] (identifying Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), Universal Mobile Telephone System (UTMS)). Wireless terminal 201 is equipped “with the software and hardware necessary to report to location system 212, via GPRS packets,” information, such as signal-strength measurements from nearby base stations. *Id.*,

[0057]. Location system 212 then “calibrate[s] the reported signal-strength measurements” in determining a location of the wireless terminal. *Id.*

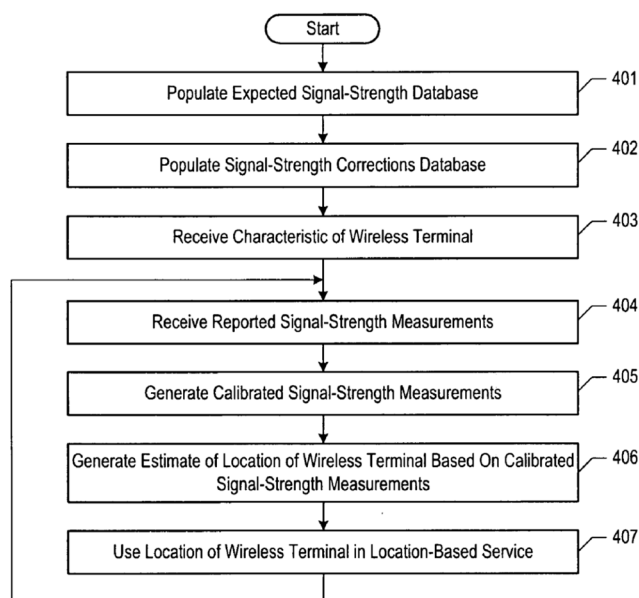
32. Location system 212 is a “data processing system that is capable of estimating the location of wireless terminal 201[,]” or “any number of wireless terminals.” APPLE-1005, [0059]. Location estimation involves “receiving reports” that “contain reported signal-strength measurements from wireless terminal 201 for the base station that are on wireless terminal 201’s list of neighboring base stations.” *Id.*, [0060]. In some embodiments, “[t]he reported signal-strength measurements in a report are made at substantially the same time, and the signal-strength measurements in different reports are made at substantially different times[,]” while in others, “a single report comprises reported signal-strength measurements made at substantially different, but documented, times.” *Id.* A POSITA would have understood that Bhattacharya contemplates generating signal strength measurement reports in different ways, e.g., by wireless terminal 201 or wireless switching center 211, and at various times.

33. Figure 3 (below) provides a detailed view of location system 212:



34. Location system 212 includes processor 301, memory 302, receiver 303, and transmitter 304. APPLE-1005, [0064]-[0065]. Processor 301 “execut[es] the operating system and user programs in memory 302, and of populating, amending, accessing, and generally managing [a] Expected Signal-Strength Database and [a] Signal-Strength Corrections Database in memory 302.” *Id.*

35. Figure 4 (below) shows an example of a location detection technique performed by location system 212.



36. The seven steps shown above reflect “[t]he overall process of estimating the location of wireless terminal 201,” which Bhattacharya informs can occur “concurrently,” “in a different order,” “together in one task,” or any combination. APPLE-1005, [0072]-[0076].

37. At task 401, “the Expected Signal-Strength Database is populated with the expected signal strengths of three signals at each location in geographic region 200[,]” including “Signal 1, Signal 2, and Signal 3.” APPLE-1005, [0085]. Each signal represents an “expected signal strength at location x, y at time t,” and “[f]or a given x, y location and time, these three functions together yield a 3-tuple of expected signal strengths designated as {E(1), E(2), E(3)}.” *Id.*, [0086]. Each expected signal-strength function is generated based on “a plurality of theoretical radio-frequency propagation models” and/or “plurality of empirical signal-strength measurements.” *Id.*, [0120]. In some embodiments, this may involve “taking

empirical measurements at various locations and by interpolating for the locations in between the sampled locations.” *Id.*, [0119]. Bhattacharya further observes that “[t]ask 401 is generally complex and can be potentially expensive,” and as a result, “performed only when necessary.” *Id.*, [0087]. Tasks 402 and 403 further involve calibrations to accommodate for “the make and model of wireless terminal.” APPLE-1005, [0088]; *see id.*, [0089]-[0090].

38. At task 404, “location system 212 periodically receives a Signal-Strength Measurement Report from wireless terminal 202 at [a] discrete relative time[.]” APPLE-1005, [0091]. Each “Signal-Strength Measurement Report” (SSMR) includes “a tuple of reported signal-strength measurements {R(1,n), R(2,n), R(3,n)},” “the real time, t, at which the signal-strength measurements were made,” and “a value of n, which indicates the relative order in which the signal-strength measurements are made.” *Id.*, [0092]-[0094]. Further, “wireless terminal 201 provides a temporal series (n, n+1, n+2, . . . , etc.)” of SSMRs “as part of the GSM protocol and the mobile-assisted hand-off process.” *Id.*, [0095]. Location system 212 calibrates the signal-strength measurements in the SSMRs based on the “calibration function for the make and model of wireless terminal 201,” to “correct—or compensate for—the signal strength measurement errors made by wireless terminal 201.” *Id.*, [0097]. The received tuple of reported signal-strength measurements ({R(1,n), R(2,n), R(3,n)}) from the wireless terminal 201 becomes a

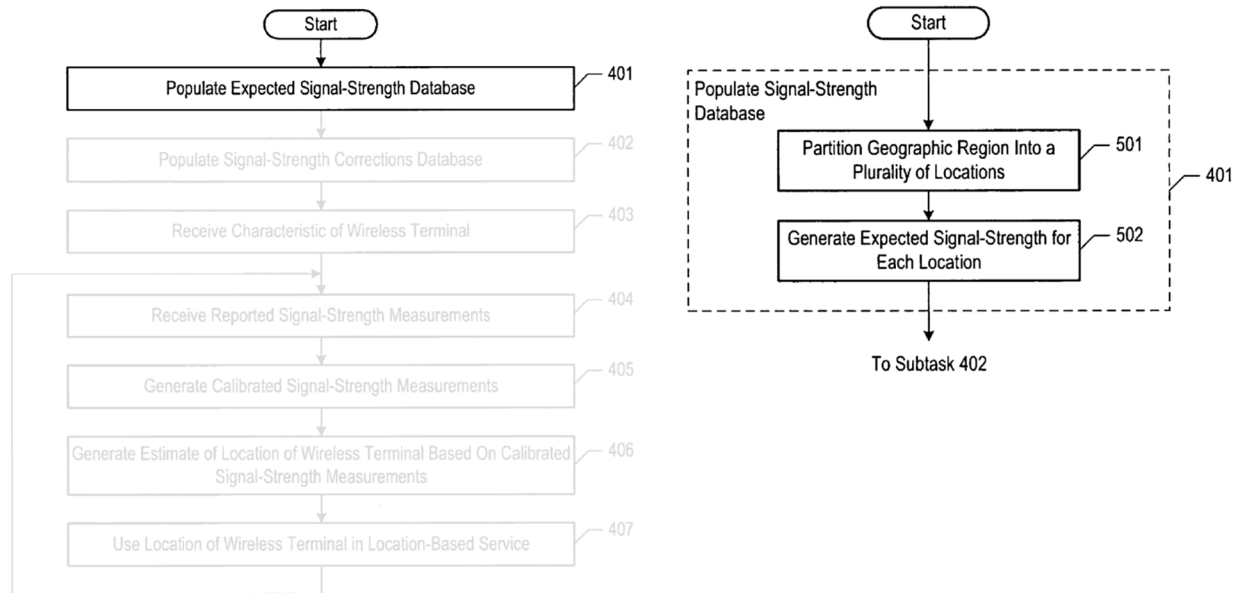
tuple of calibrated signal-strength measurements ($\{S(1,n), S(2,n), S(3,n)\}$), which is a function of $\{R(1,n), R(2,n), R(3,n)\}$ and the values in the calibration database created in step 402 for the make and model of wireless terminal 201. *See* APPLE-1005, [0097], [0168]-[0169].

39. It was well known as of the Critical Date that various wireless standards/protocols (including Bhattacharya's preferred GSM protocol) utilize "Network Measurement Reports (NMRs)" to report signal strengths with respect to one or more nearby base stations, and that such NMRs would either have been synonymous with or at least one known form of the "Signal-Strength Measurement Reports" upon which Bhattacharya's systems and methods rely to estimate a mobile terminals location. *See, e.g.*, APPLE-1009, 16:19-23 (relying upon "existing GSM Network Measurement Report (NMR)"), 20:11-20 ("The Measurement Report (MR) is sent periodically during an active voice or data session . . . and contains downlink (base station to mobile device) measurements on neighboring transmitters This technique, called mobile-assisted-handoff (MAHO), is common to most cellular radio networks including US TDMA (IS-136), CDMA, GSM, and UMTS."); APPLE-1010, 43 ("When in RR connected mode, the mobile station regularly sends MEASUREMENT REPORT messages to the network. These messages contain measurements results about reception characteristics from the current cell and from neighbour cells."). A POSITA would

have understood or at least found it obvious that the “signal-strength measurements” contained in “Signal-Strength Measurement Reports” described by Bhattacharya would have been received, at least in part, from the well-known reception of the NMRs that are standard in various cellular radio networks (e.g., GSM). Because these NMRs are regularly sent as a part of these various wireless standards (*see* APPLE-1005, [0095]; APPLE-1009, 20:11-20; APPLE-1010, 43), a POSITA implementing Bhattacharya’s system and method would have found it obvious to utilize the signal strength measurements contained in these NMRs, because they would provide the information required by Bhattacharya without the need to further add data or messages to the existing cellular radio networks.

40. At task 406, “location system 212 generates a current estimate of the location of wireless terminal 201” based on “the tuple of calibrated signal-strength measurements $\{S(1,n), S(2,n), S(3,n)\}$,” “expected signal-strength tuples for all locations $\{E(1,x,y,t), E(2,x,y,t), E(3,x,y,t)\}$ at the time when the measurements underlying $\{S(1,n), S(2,n), S(3,n)\}$ were made,” and “the cumulative probability distribution for the location of wireless terminal 201...based on all of the [SSMRs] up to and including Report n-1.” APPLE-1005, [0098]-[0101]. At task 407, location system 212 “transmits the location estimated in task 406 to another entity” for “use in a location-based served (e.g., Emergency 911 Service, etc.).” *Id.*, [0103].

41. Bhattacharya offers further detail in each of the seven tasks depicted in Figure 4 in other figures (reproduced and referenced below). Figure 5 (below, right) provides additional detail on task 401 of Figure 4 (below, left).

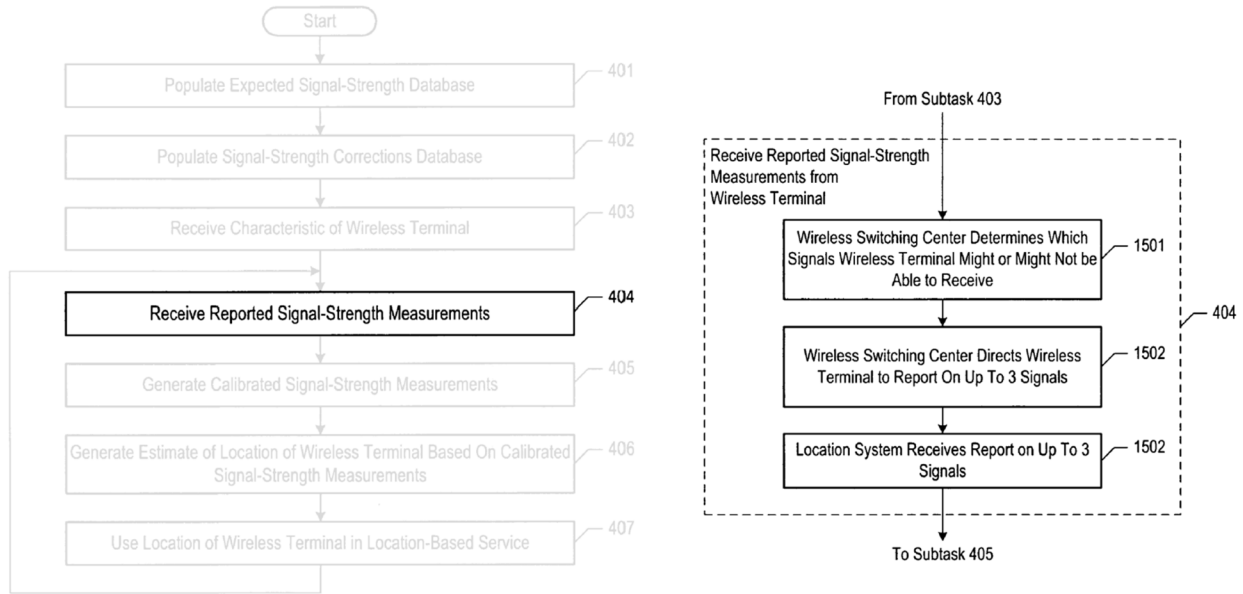


42. As shown above, at subtask 501, “a rectangular grid of X by Y tessellated squares is overlaid onto geographic region 200” where “each square represents a location.” APPLE-1005, [0106]. At subtask 502, “expected signal-strength functions $E(1,x,y,t)$, $E(2,x,y,t)$, $E(3,x,y,t)$ ” are generated based on a combination of “a plurality of theoretical radio-frequency propagation models” and “a plurality of empirical signal-strength measurements.” *Id.*, [0112]-[0117]. The expected signal strength functions are “a function of x and y” since “the topography of [a] region and the presence of buildings, trees, and other radio-frequency obstacles severely alter” signal propagation. *Id.*, [0113]. Further, “expected signal strength at each location is dynamic and changes,” e.g., “with

time as the atmospheric and meteorological conditions change[.]” which is why “expected signal-strength functions are a function of time.” *Id.*, [0014].

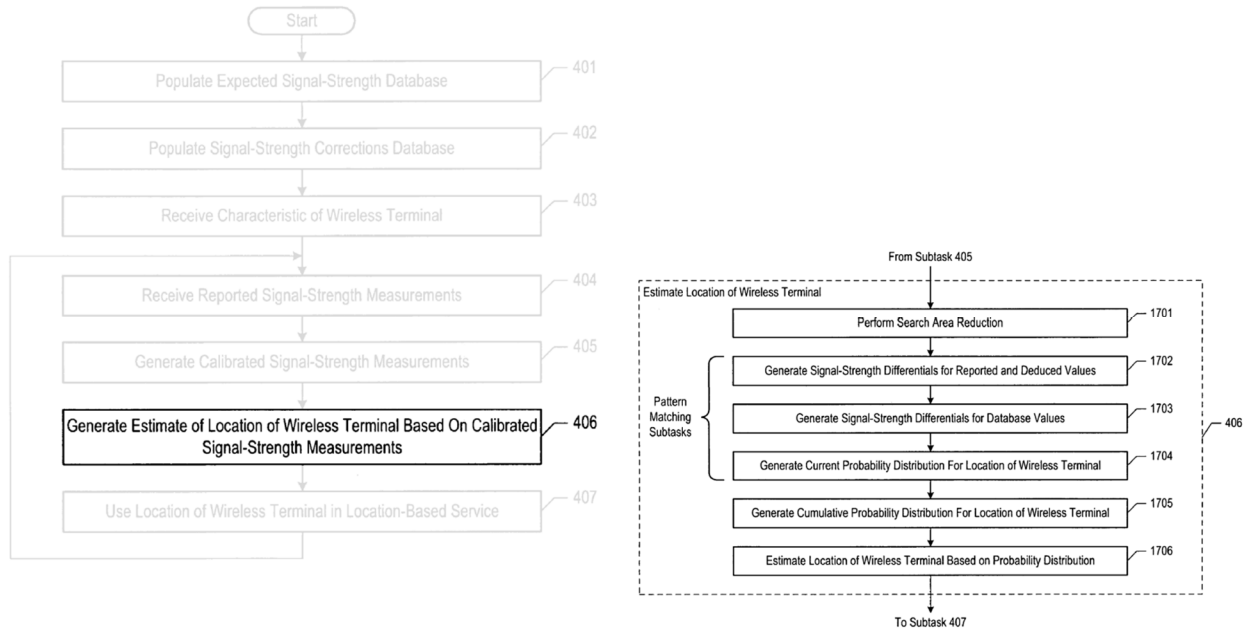
43. Bhattacharya does not address storage of expected signal-strength functions to accommodate time-dependent atmospheric and meteorological changes. *See generally* APPLE-1005, [0085], [0105]-[0127]. However, such data storage configurations were well-known in the art as of the Critical Date. For example, as discussed in Sections IX.B and XI.A, Spain provides an example of a database configuration that stores expected values for signal-strength measurements, including storing values for environmental conditions. APPLE-1006, [0076], [0086], [0102], [0202]. Another example example is Bahl (APPLE-1008), which provides an implementation where the database is implemented as a table recording the location index and corresponding signal strength measurements from three base stations at that location. APPLE-1008, Abstract, 2:7-27.

44. Figure 15 (below, right) provides additional detail on task 404 in Figure 4 (below, left). Bahl [] provides one such implementation, where the database is implemented as a table recording the location index and corresponding signal strength measurements from three base stations at that location.



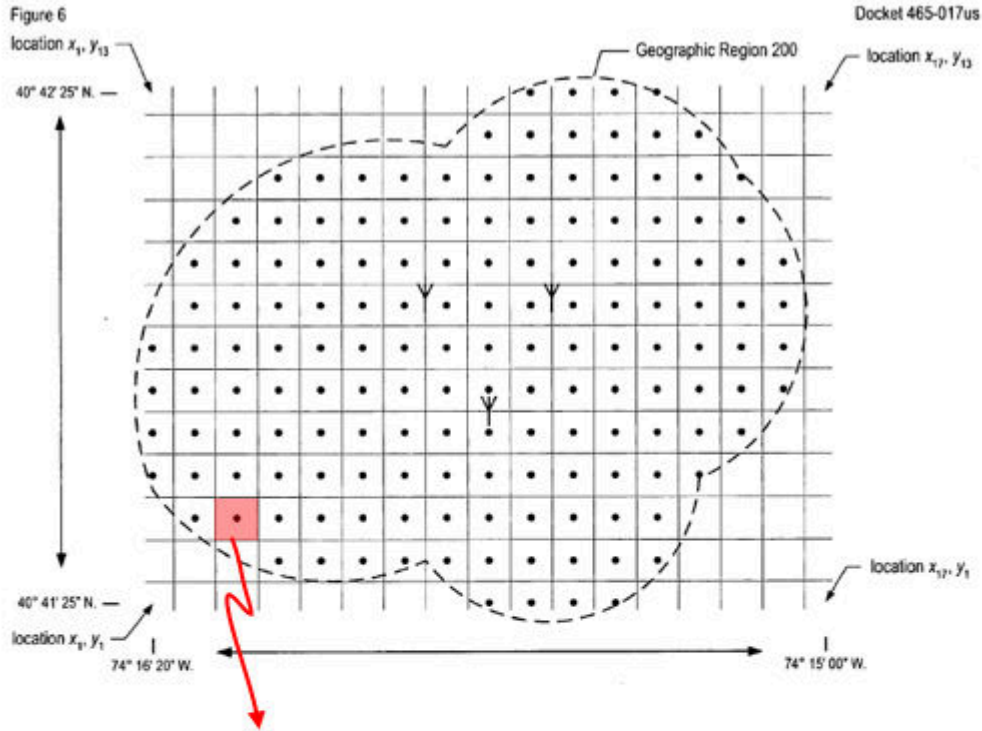
45. As shown above, at subtasks 1501 and 1502 relates to coordination between wireless switching center 211 and wireless terminal 201, which permits wireless terminal 201 “to attempt to receive and to report back a signal-strength value for the signals that wireless terminal 201 is able to receive and distinguish.” APPLE-1005, [0159]. At subtask 1503, location system 212 receives an SSMR from wireless terminal 201 that includes “a tuple of reported signal-strength measurements $\{R(1,n), R(2,n), R(3,n)\}$,” “the time, t , at which the signal-strength measurements were made,” and “a value of n , which indicates the relative order in which the signal-strength measurements are made.” *Id.*, [0160]-[0163].

46. Figure 17 (below, right) provides additional detail on task 406 in Figure 4 (below, left).



47. As shown above, at subtask 1701, processor 301 (of location system 212) uses “search area reduction” to “reduce the number of candidate locations that must be processed” by excluding candidates with a probability “calculated to be very close to zero.” APPLE-1005, [0173]. The reduction is dictated by Equation 6, which a POSITA would have understood to be a direct comparison of a given received calibrated signal tuple (e.g., $\{S(1, n), S(2, n), S(3, n)\}$), as well as a discrete number Ω of the previously received calibrated signal tuples, against each of the expected signal tuples in the entire search area. *See* APPLE-1005, [0173]-[0174]. If the difference between all Ω of the recently received calibrated signal tuples and the expected signal value E for a given location (x, y) is greater than a threshold value Ψ , then it is assumed that the probability that the mobile terminal is at location (x, y) is very low. *Id.* An example of this calculation is illustrated

below, where Ω (i.e., the number of previously received signal strength reports used in this calculation) is assumed to be 3 for the sake of simplicity.



For each of the grid points within the geographic area, including location (x_3, y_3) highlighted in red, *exclude the location if and only if:*

- $|E(1, x, y, t) - S(1, n)| \geq \Psi$; AND
- $|E(1, x, y, (t @ n-1)) - S(1, n-1)| \geq \Psi$; AND
- $|E(1, x, y, (t @ n-2)) - S(1, n-2)| \geq \Psi$; AND
- $|E(1, x, y, (t @ n-3)) - S(1, n-3)| \geq \Psi$; AND
- $|E(2, x, y, t) - S(2, n)| \geq \Psi$; AND
- $|E(2, x, y, (t @ n-1)) - S(2, n-1)| \geq \Psi$; AND
- $|E(2, x, y, (t @ n-2)) - S(2, n-2)| \geq \Psi$; AND
- $|E(2, x, y, (t @ n-3)) - S(2, n-3)| \geq \Psi$; AND
- $|E(3, x, y, t) - S(3, n)| \geq \Psi$; AND
- $|E(3, x, y, (t @ n-1)) - S(3, n-1)| \geq \Psi$; AND
- $|E(3, x, y, (t @ n-2)) - S(3, n-2)| \geq \Psi$; AND
- $|E(3, x, y, (t @ n-3)) - S(3, n-3)| \geq \Psi$

APPLE-1005, Figure 6 (annotated, illustrating subtask 1701).

48. Once processor 301 reduces the number of candidate locations in subtask 1701, it begins the subtasks related to generating the probability that the

received signals are associated with each of the remaining locations within the geographic area. *See generally* APPLE-1005, [0179]-[0207]. However, unlike in subtask 1701, the processor 301 does not directly compare the received calibrated signal tuple S (e.g., $\{S(1, n), S(2, n), S(3, n)\}$) with the expected signal tuples E (e.g., $\{E(1, x, y, t), E(2, x, y, t), E(3, x, y, t)\}$) for each of the remaining candidate locations. *See* APPLE-1005, [0179]-[0189], [0195]. Instead, in subtasks 1702 and 1703, the processor 301 converts the received calibrated signal tuple S and the expected signal tuples E for each of the candidate locations into a set of differentials ΔN and ΔE that are comparisons of adjusted signals within each tuple.¹ APPLE-1005, [0179]-[0188].

¹ Bhattacharya describes certain embodiments where reported signal-strength that are deemed “saturated” (“at one of the bounds of the range at which a measurement can be reported,” e.g., -47 dBm, -110dBm) are removed prior to computing signal-strength differentials since “their saturated nature prevents the true magnitude they represent from being known with enough certainty...” APPLE-1005, [0179], [0180]. Yet Bhattacharya also contemplates other embodiments where reported signal-strength measurements are provided as “GPRS packet data and these reported signal-strength measurements are not [] bounded by

49. Bhattacharya explains that the purpose of generating and comparing these signal-strength differentials ΔN and ΔE , as opposed to directly comparing the received calibrated signal tuple S and the expected signal tuples E , is that “various factors including the condition of the wireless terminal’s antenna, the state of its battery, and whether the terminal is inside a vehicle” can affect the reported signals for a wireless terminal, even when it is the same make and model and at the same location. *See* APPLE-1005, [0021]-[0023]. By comparing the signal-strength differentials ΔN and ΔE generated in subtasks 1702 and 1703, Bhattacharya teaches that these biases owing to the state of the wireless terminal can be ameliorated. *See id.*

50. Bhattacharya describes the generation of the signal-strength differentials ΔN and ΔE with respect to equations 7 and 8. *See* APPLE-1005, [0181]-[0188]. An example of a differential ΔN for received calibrated signal tuple

the -47 dBm to -110 dBm domain limitation imposed on GSM terminals...” *Id.*, [0164]. Thus, a POSITA would have understood and found obvious that, embodiments of Bhattacharya that use GPRS packets for communication are not subject to saturation, and therefore, would not require removal prior to computing signal-strength differential. For simplicity of explanation, the description of Bhattacharya that follows assumes there are no saturated values.

S and a differential ΔE for an expected signal tuples E at location x_1, y_1 is shown below:

$$\Delta N = [\{S(2, n) - S(1, n)\}, \{S(2, n) - S(3, n)\}]$$

$$\Delta E = [\{E(2, x_1, y_1, t) - E(1, x_1, y_1, t)\}, \{E(2, x_1, y_1, t) - E(3, x_1, y_1, t)\}]$$

where t is the time when the measurements underlying $\Delta N(k,n)$ were made. *See* APPLE-1005, [0181]-[0188]. In this example, each of the signal strength differentials ΔN and ΔE has two elements (m-1), instead of the three (m) that are in their associate signal tuple S and E, respectively. APPLE-1005, [0181].

51. At subtasks 1704 and 1705, processor 301 generates probability distributions for the “location of wireless terminal 201” (in subtask 1704, a probability distribution is based on the “most recently received reported signal-strength measurements; in subtask 1705, a probability distribution is based on “all of the received reported signal-strength measurements”). APPLE-1005, [0189]. As described above with respect to subtasks 1702 and 1703, these probabilities are based on statistical comparisons of the signal strength differentials ΔN and ΔE , instead of the received calibrated signal tuple S and expected signal tuples E, though the signal strength differentials ΔN and ΔE are simply functions of the tuples S and E. *See* APPLE-1005, [0189]-[0206]. In other words, the estimation is accomplished by “pattern matching the pair-wise differentials of the calibrated

signal strengths to the pair-wise differentials of the expected signal strengths.”

APPLE-1005, [0023], [0024], [0127].

52. At subtask 1706, the probability distributions are evaluated to estimate the location of wireless terminal 201. *Id.*, [0207]. This involves “pattern matching the pair-wise differentials of the calibrated signal strengths to the pair-wise differentials of the expected signal strengths.” *Id.*, [0023], [0024], [0127]. In essence, Bhattacharya describes combining the probability distribution for the most recently received signal strength report (generated in subtask 1704) and “aged” versions of the probability distribution for previously received signal strength reports from the same wireless terminal 201 (generated in subtask 1705), and then selecting the location associated with the greatest probability. *See* APPLE-1005, [0195]-[0207]. In essence, Bhattacharya describes combining the probability distribution for the most recently received signal strength report (generated in subtask 1704) with “aged” versions of the probability distribution for previously received signal strength reports from the same wireless terminal 201 (generated in subtask 1705), and then selecting the location associated with the greatest probability. *See* APPLE-1005, [0195]-[0207].

53. As discussed above, Bhattacharya’s disclosure of location estimation is consistent with techniques described in the ’494 patent specification. The operations are performed in a similar order and for a similar purpose, and further

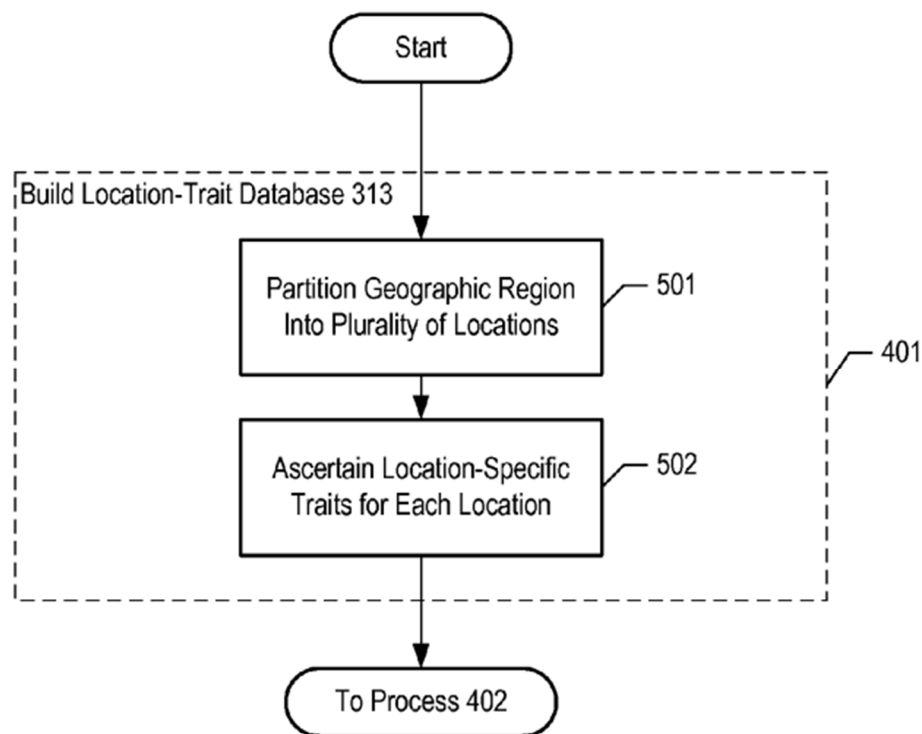
results in a similar location estimation outcome. For example, location estimation in Bhattacharya and the '494 patent specification each involve the same type of data (signal strength values, network reports) and the same type of data modification (difference calculations). In the '494 patent specification, the “modified network measurement data” may be generated by computing “differences in parameters between the serving cell and the [neighboring cells], e.g., “[i]f an original NMR received at the [position determining equipment 50] had the form $NMR1=[P1, P2, P3, TA1]$ ” where P1, P2, and P3 are base station power levels, then “the modified NMR may be represented by: $NMR_modified=[0, P1-P2, P1-P3, TA1]$.” APPLE-1001, 5:15-31. Bhattacharya similarly describes generation of “signal-strength measurement differentials” between “different pairs of signal-strength measurements $\{N(1,n), \dots N(m,n)\}$.” APPLE-1005, [0182].

B. Spain

54. Like Bhattacharya, Spain describes techniques for populating a database (e.g., location-trait database 313) with expected values for traits to be used for comparison against measured values in estimating the location of a wireless terminal at an unknown location. APPLE-1006, [0006]. In Bhattacharya, an “expected signal-strength database” is a database that stores expected signal strength values for locations within a geographic region. APPLE-1005, [0112]-

[0127]. In Spain, a “location-trait database 313” is a “database that maps each of a plurality of locations to one or more expected traits associated with a wireless terminal at that location.” APPLE-1006, [0066].

55. Figure 5 (below) shows Spain’s technique for building a location-trait database 313:



56. At process 501, “geographic region 220 is partitioned into $B(T,N)$ locations,” where “ $B(T,N)$ varies as a function of calendrical time T and the environmental conditions N .” APPLE-1006, [0072]. For instance, “calendrical time” is defined as “the time as denominated in one or more measures (e.g., seconds, minutes, hours, time of day, day, day of week, month, month of year,

year, etc.).” *Id.*, [0035]. Further, “environmental conditions” are defined to “include one or more physical aspects of the environment,” e.g., “the astronomical conditions, atmospheric conditions, the quantity and density of radio traffic, the quantity and density of vehicular traffic, road and sidewalk construction, etc.” *Id.*

57. Further, “the number of locations that geographic region 220 is partitioned into is static.” APPLE-1006, [0072]. Each “location” also includes various types of information, including “a unique identifier,” “coordinates” that “define its scope (e.g., position, area, volume, etc.,” “expected value $E(b, T, N, W, Q)$ for each trait, Q , when wireless terminal W is at location b at calendrical time T given environmental conditions, N ,” among others. APPLE-1006, [0076]-[0082]. A POSITA would have understood and found obvious that the examples of information specified for each location are stored in location-trait database 313.

C. Meunier

58. Meunier is focused on techniques for “detecting the proximity of mobile devices in a wireless network.” APPLE-1007, [0001]. One example is the “use of a wireless local-area network to detect the location of a device within [an] area covered by the network.” *Id.*, [0002]. Like Bhattacharya, Meunier’s location estimation technique “relies on characterizing each place by the received signal strength of the wireless access points that cover an area.” *Id.* After calibration, Meunier leverages several well-known techniques for estimating a location of a

mobile device, e.g., by “compar[ing] measured wireless signal strength to a table of wireless signal strengths and known locations” to “find[] the table entry with the closest signal strength to the measured signal strength and determine[] its location by reference to the found table entry.” *Id.*

59. Yet Meunier observes that location estimation techniques using signal strength have several disadvantages, where “changes in the signal strength result in an inherent unreliability of the detected location.” APPLE-1007, [0003]. Further, “it is difficult to achieve large improvements in the reliability of the raw location information derived from a comparison of measured signal strength against the signal strengths recorded during a calibration phase.” *Id.*, [0013].

60. To address these disadvantages, Meunier proposes pre-processing steps where “statistical correction algorithms” may be employed to “chang[e] how the raw signal strength measurements is used” using “additional information” prior to location estimation. *Id.*, [0003], [0013]. This additional information includes, for example, movement detected by a motion sensor in a mobile device and using the device movement to determine whether to further process raw signal strength measurements. *Id.* One examples of a motion detector used for detecting device movement is an accelerometer. APPLE-1007, [0012]. Meunier also teaches embodiments where the motion detector is a “simple binary motion detector.” *Id.*, [0017]. In Meunier, the device movement monitoring is “concerned only with

whether the mobile device is moving more than a certain amount (some predetermined threshold) or not.” APPLE-1007, [0014].

61. To evaluate device movement, “a cut off threshold” is used to determine “a Boolean value indicating if movement is above the threshold,” which allows use of “less expensive” sensors. *Id.* Further, an example of a statistical correction algorithm is to “use a moving window of N signal strength samples” to compute an “average value and standard deviation of the signal strength” for each base station.” *Id.*, [0016]. Where additional information (e.g., device movement) indicates use of raw signal strength measurements may be changed, Meunier envisions applying statistical correction algorithms to change raw values (e.g., by computing average values for each base station based on raw signal strength values) and using the changed values (e.g., average values) in location estimation.

62. Meunier accounts for two specific scenarios that each leverage monitoring device movement (e.g., using a Boolean value from the motion detector) to “determine the manner in which the raw location information is treated by [a] location detection module.” APPLE-1007, [0015]. In a first scenario, device movement is below the cut off threshold, which permits use of “statistical correction algorithms” to change raw signal strength values (e.g., computing average signal strength values) and then using the changed values for location estimation to “improve accuracy of the location detection.” *Id.*, [0016], [0006],

[0007]. In the second scenario, device movement is above the cut off threshold and the location is estimated based on solely on the instantaneous signal strength information. *Id.*, [0017]. While these two scenarios involve selection of different types of values (average signal strength values, instantaneous signal strength values) for use in location estimation, a POSITA would have understood and found obvious that the selection of values does not meaningfully impact the comparison technique contemplated to be used by Meunier for location estimation. *See, e.g.*, APPLE-1007, [0002] (“compar[ing] measured wireless signal strength to a table of wireless signal strengths and known locations” to “find[] the table entry with the closest signal strength to the measured signal strength” and “determine[] its location by reference to the found table entry”). Indeed, a POSITA would have understood and found obvious that, because computed average values are base station-specific, an average value computed for a particular base station would provide similar signal strength information as instantaneous value for that particular base station.

X. [GROUND 1A] – BHATTACHARYA ANTICIPATES CLAIMS 1, 2, 5, 9, 12, 14, 16, AND 18-22

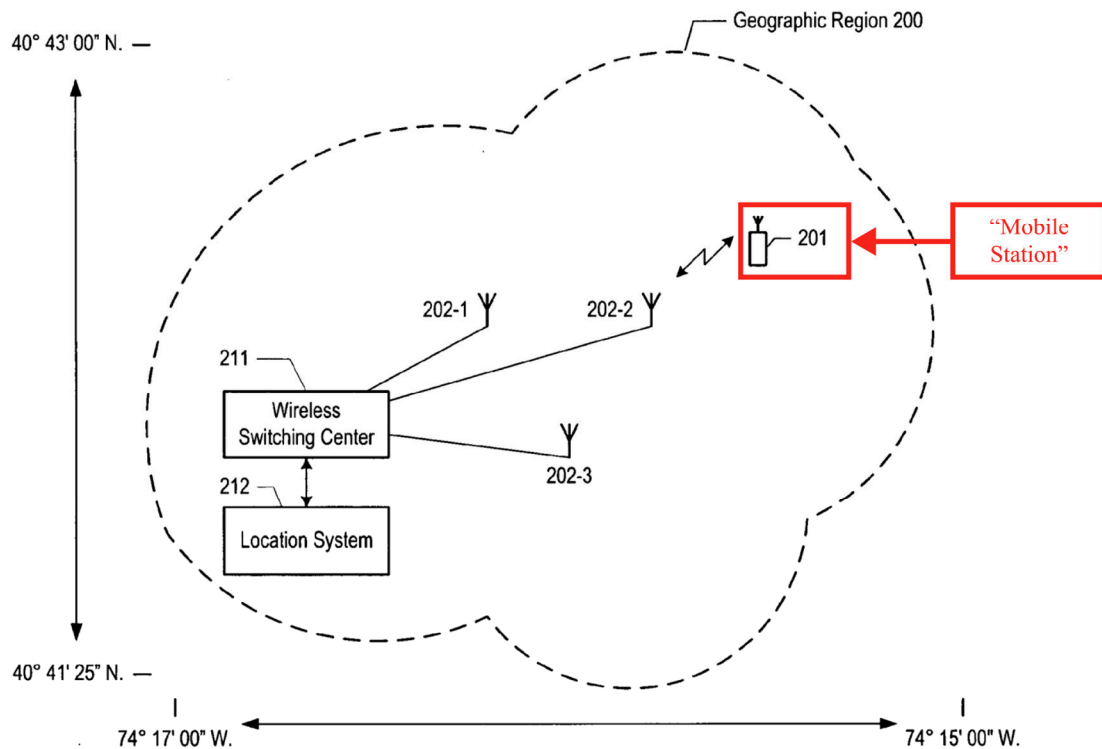
A. Analysis

1. Claim 1

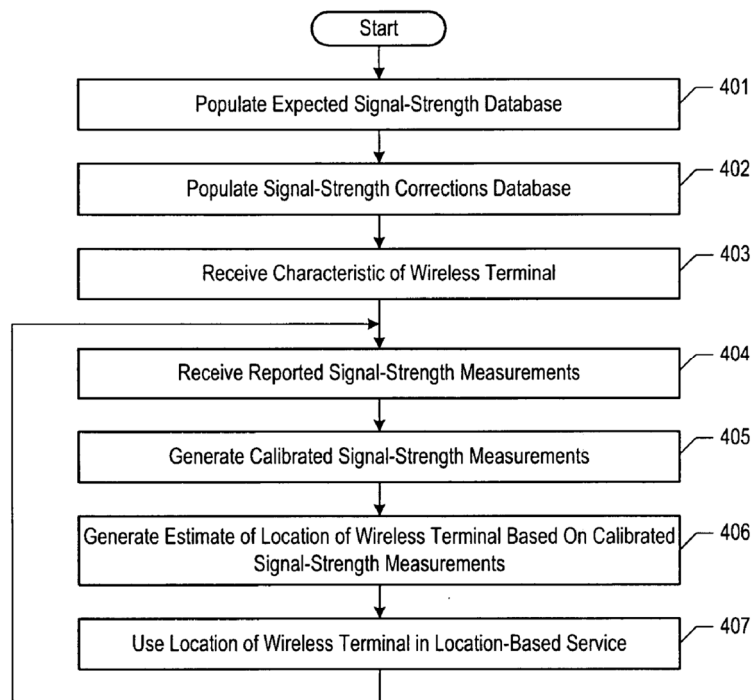
[1.1] A method for determining a location of a mobile station, comprising:

63. Even if the preamble were properly limiting (it is not), Bhattacharya discloses it. As shown below, Bhattacharya includes a wireless terminal 201 (“*mobile station*”). As shown in Figure 2 (annotated below), wireless terminal 201 is a “GSM-compliant wireless terminal with GPRS packet data capability,” and can “operate in accordance with other protocols,” such as UTMS, CDMA-2000, IS-136 TDMA, Short Message Service, and Circuit Switched Data. APPLE-1005, [0056]. As shown in Bhattacharya’s Figure 2 below, the system can include other components, such as wireless switching system center 211, location system 212, and base stations 202-1, 202-2, 202-3. APPLE-1005, [0051].

Figure 2



64. Bhattacharya further provides “[a] process and machine for estimating the location of the [the] wireless terminal.” APPLE-1005, Abstract. The location is estimated based on signal strength measurements and, in particular, “by comparing the signal strength [the wireless terminal 201] currently observes against a map or a database that correlates locations to signal strengths.” *Id.* As discussed in Section XI.A, tasks involved in Bhattacharya’s location estimation technique are shown in Figure 4 (below):

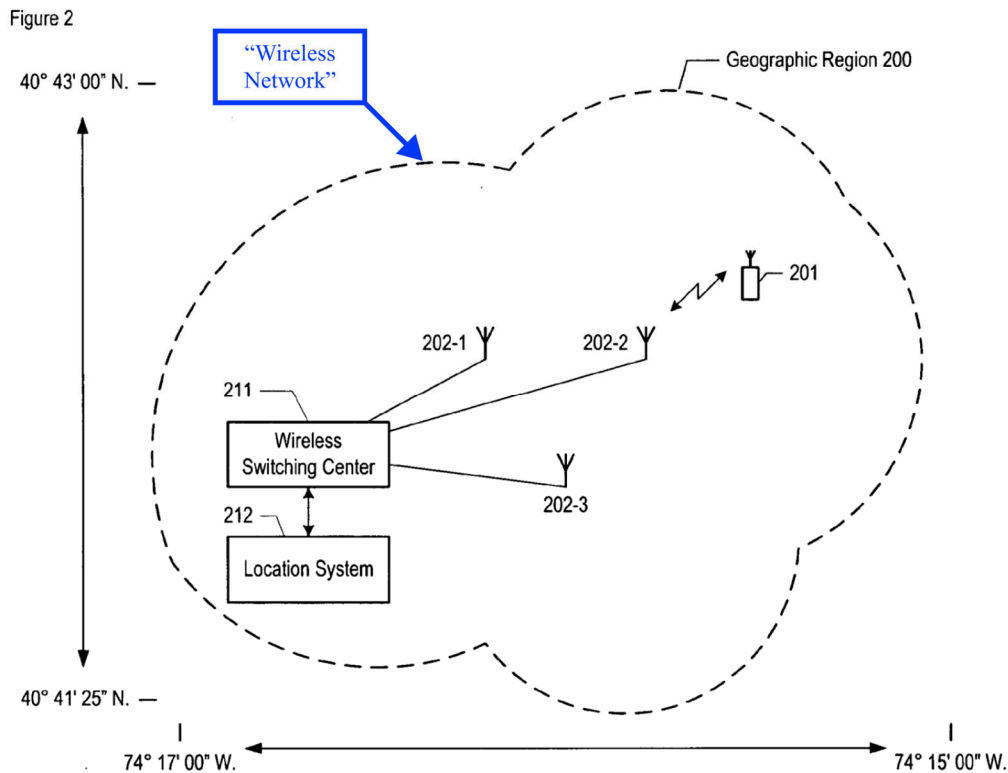


[1.2] providing a database of previously-gathered calibration data for a predetermined region in a wireless network;

65. Bhattacharya’s system operates within geographic region 200 (“***predetermined region***”) and provides wireless telecommunications services through a network (“***wireless network***”) for the region 200. APPLE-1005, [0051].

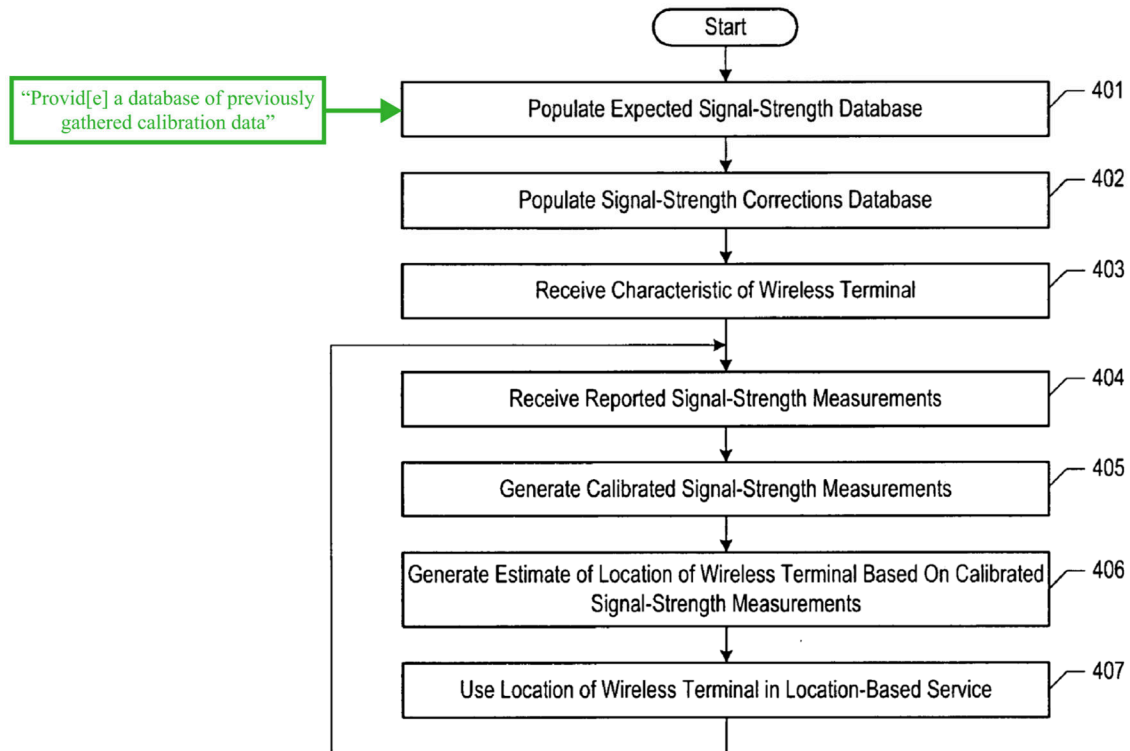
A POSITA would have understood that region 200 is predetermined at least because the expected signal strength of signals at particular locations are stored in an expected signal strength database indicating that region 200 and locations therein would have been predetermined. APPLE-1005, [0085].

66. Figure 2 (annotated below) shows the wireless network including wireless terminal 201, wireless switching center 211, location system 212, and base stations 202-1, 202-2, 202-3. *Id.*

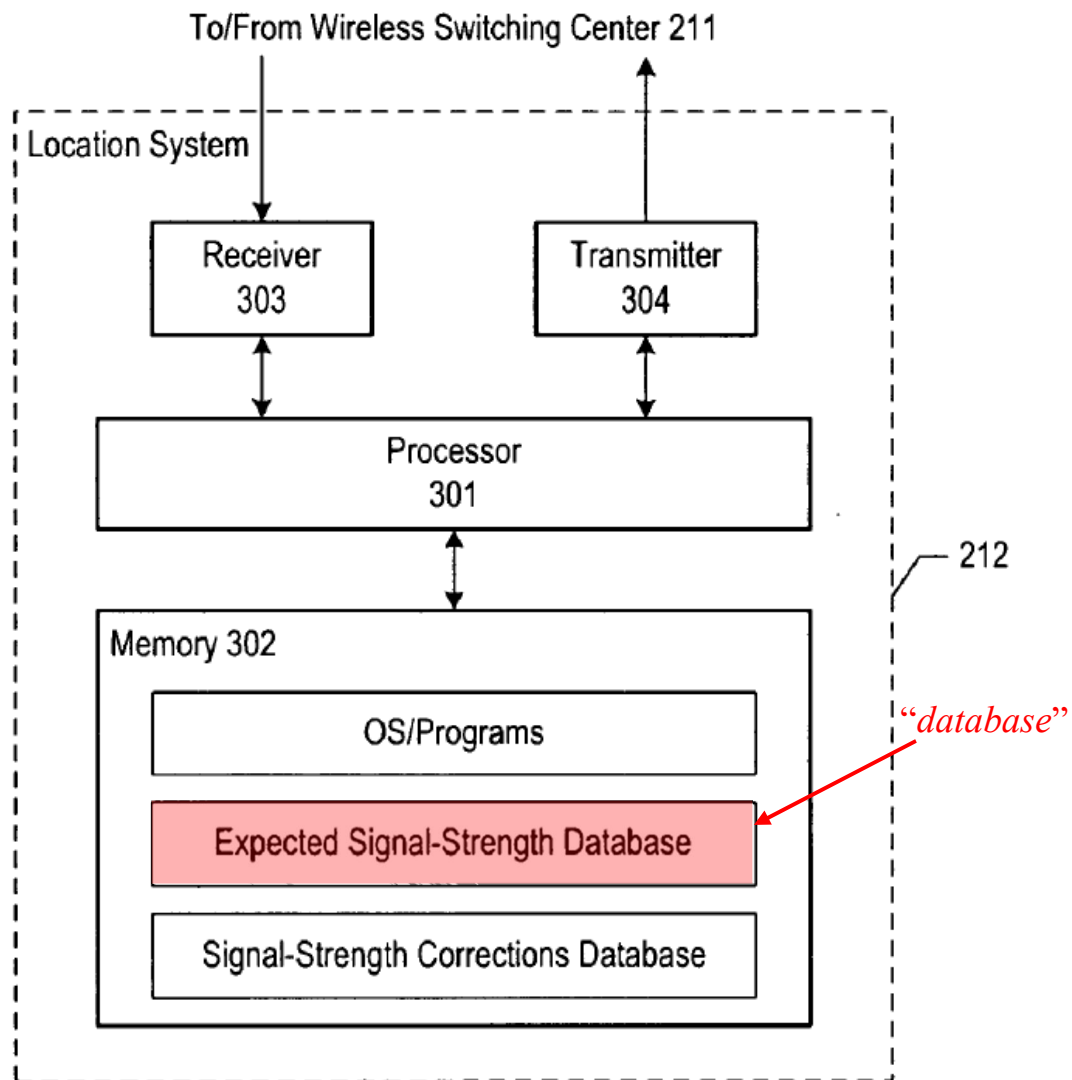


67. Figure 4 (annotated below) shows tasks involved in Bhattacharya's location estimation technique. At task 401, the expected signal-strength database ("**database**"), an example of which is shown below in Bhattacharya's FIG. 3, is

populated to store various types of data representing expected values later used for location estimation within geographic region 200 (“*calibration data for a predetermined region in a wireless network*”). APPLE-1005, [0085]-[0087], [0064]-[0068], [0039].



APPLE-1005, FIG. 4.



APPLE-1005, FIG. 3.

68. Data stored in Bhattacharya's expected signal-strength database is an example of network measurement data associated with a defined geographic location. As discussed for [5], *infra*, the stored data includes expected signal-strength measurements of known locations of base stations within a geographic

region. For example, “Signal 1 is the control channel broadcast by base station 202-1 and its expected signal strength at location x, y at time t...” APPLE-1005, [0086]. Further, since base station locations of a geographic region are known when populated in the expected signal-strength database, each base station location is a known location. *Id.*

69. Once the database is populated, the data stored in the populated database includes, for example, expected signal-strengths ($E(1,x,y,t)$, $E(3,x,y,t)$, $E(3,x,y,t)$ (*id.*, [0086]), e.g., expected signal-strengths for locations in region 200 (Signal 1, Signal 2, Signal 3) (APPLE-1005, [0085]), which, in certain embodiments, is based on “one or more empirical signal-strength measurements” (*id.*, [0120]).

70. Various disclosures in Bhattacharya indicate that data stored in the expected signal-strength database represents “***previously-gathered calibration data***” under its plain meaning. The phrase “previously-gathered” is a relative term requiring a gathering of “calibration data” prior to a reference time point. Through antecedent basis, reference to the term “previously-gathered calibration data” in a subsequent claim limitation ([1.6]) indicates that, under plain meaning, the “previously-gathered” requirement may be met at least by data that exists in the signal-strength database prior to execution of steps of subsequently recited claim limitations ([1.3]-[1.6]).

71. For example, through the ordering of tasks depicted in Figure 4, Bhattacharya indicates that the expected signal-strength database is populated (i.e., data is stored in the database) at task 401, prior to the receipt of signal-strength measurements by wireless terminal 201 and/or the collection of an SSMR (which includes the signal-strength measurements) by the location system 212 from a wireless terminal by computing signal-strength differentials in task 406. APPLE-1005, [0098]-[0101], [0179], FIG. 17 (subtask 1702), FIG. 4. Further, occurrence of intermediate tasks, e.g., the population of signal-strength corrections database in task 402, receipt of the characteristics of wireless terminal in task 403, confirms that data to be stored in the database is populated (e.g., gathered) prior to receipt of at least some of the signal-strength measurements in task 404 and modification of the signal-strength measurements in task 406. *Id.*, [0089]-[0090]. Thus, Bhattacharya's expected signal-strength database is populated prior to collection of signal-strength measurements in an SSMR from wireless terminal 201. Bhattacharya confirms this through contemplation of alternative embodiments in which "some of these tasks" occur "together in one task," confirming that its disclosure contemplates sequential execution of tasks other than the order depicted in its Figure 4 process. APPLE-1005, [0072].

72. Finally, the collection of expected values for storage in the database prior to collection of observed network data is consistent with disclosure in the

'494 patent specification corresponding to the “*previously-gathered calibration data*.” In the '494 patent specification, “calibration data is typically collected in an outdoor environment” for “greater ease of performing automated calibration procedures.” APPLE-1001, 1:27-38. Further, “calibration data may be obtained from data collection devices during field test operations, and/or from [mobile stations] or other communication devices within the general area of the [non-uniform grid points].” *Id.*, 4:1-14. Like the examples of calibration data described in the '494 patent specification, expected signal-strength measurements in Bhattacharya may be “generated by taking empirical measurements at various locations,” specific examples of which were well-known by the Critical Date. APPLE-1005, [0119].

73. By the Critical Date, a POSITA would have known that least one method of collecting the empirical measurements described by Bhattacharya would have been to transport testing devices around the geographic region 200 and measure the signal strength for each of the three signals received from the three base stations (202-1, 202-2, and 202-3) and the geographic location of the testing device (e.g., using a GPS receiver connected to the testing device) in order to determine the (x,y) associated with each of the three signals. *See, e.g.*, APPLE-1001, 4:3-15. A POSITA would have also known that one method of generating expected signal strength for a grid point would have been to collect multiple

empirical measurements within the grid square surrounding the grid point and average the multiple empirical measurements. *Id.*, APPLE-1011, 7:28-44. By averaging multiple empirical measurements within the grid square surrounding the grid point, a POSITA would have understood or at least found it obvious that some of the effects of fast fading could be removed. *See, e.g., id.*, 7:50-56. In this regard, a POSITA would have understood or at least found it obvious that the expected signal-strength functions $\{E(1,x,y,t), E(2,x,y,t), \text{ and } E(3,x,y,t)\}$ for a given grid point within the geographic region 200 may represent an average of calibration data from multiple locations within the grid square, and not simply represent the storage of the calibration data itself. *See id.*

[1.3] collecting observed network measurement data

74. In Bhattacharya, wireless terminal 201 measures (“collect[s]”) reported signal-strength measurements (“observed network measurement data”) included in an SSMR. APPLE-1005, [0091]. Each SSMR includes “a tuple of reported signal-strength measurements $\{R(1,n), R(2,n), R(3,n)\}$,” and specifies “real time, t , at which the signal-strength measurements were made” and “the relative order in which the signal-strength measurements are made.” *Id.*, [0091]-[0094]. Referring to the Figure 2 example, the SSMR includes three signals, “Signal 1, Signal 2, and Signal 3” measured by the wireless terminal 201. APPLE-1005, [0158]-[0160]; *see also* [91], [70], FIG. 4.

[1.4] the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;

75. As discussed above for [1.3], in Bhattacharya, reported signal-strengths measurements (“***observed network measurement data***”) are included in the SSMR provided by wireless terminal 201 to location system 212. APPLE-1005, [0091]. The SSMR includes “a tuple of reported signal-strength measurements R(1,n), R(2,n), R(3,n),” where “R(1,n)” is “signal-strength measurement of Signal 1 as measured by wireless terminal 201 at time t,” “R(2,n)” is “signal-strength measurement of Signal 2 as measured by wireless terminal 201 at time t,” and “R(3,n) is the nth reported signal-strength measurement of Signal 3 as measured by wireless terminal 201 at time t.” *Id.*, [0092]-[0094]. Thus, signal-strength measurements (“***observed network measurement data***”) are measured by the wireless terminal 201 (“collected by the mobile ***station***”). Further, the wireless terminal 201 provides signal-strength measurements in an SSMR to the location system 212 for location estimation, and thus, the reported signal-strength measurements are “***transmitted to the network.***” APPLE-1005, [0057]-[0060].

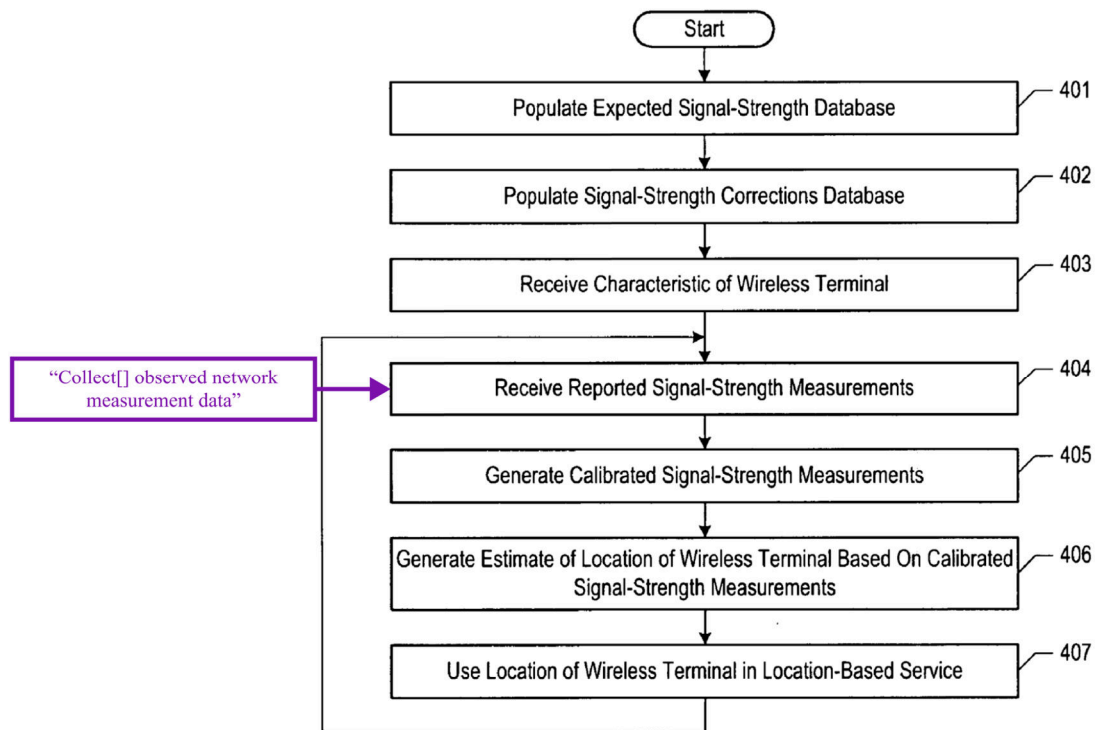
[1.5] modifying said observed network measurement data; and

76. As noted above in [1.3]-[1.4], the wireless terminal 201 collects signal-strength measurements (“***observed network measurement data***”). APPLE-1005, [0091], [0064], [0120]-[0123]. As shown below in FIG. 4, after collecting or receiving the reported signal strength measurements in task 404, the “reported

signal-strength measurements $\{R(1,n), R(2,n), R(3,n)\}$ from task 404 and the calibration function for the make and model of wireless terminal 201 [are used] to generate a tuple of calibrated signal-strength measurements $S(1,n), S(2,n), S(3,n)\}$.

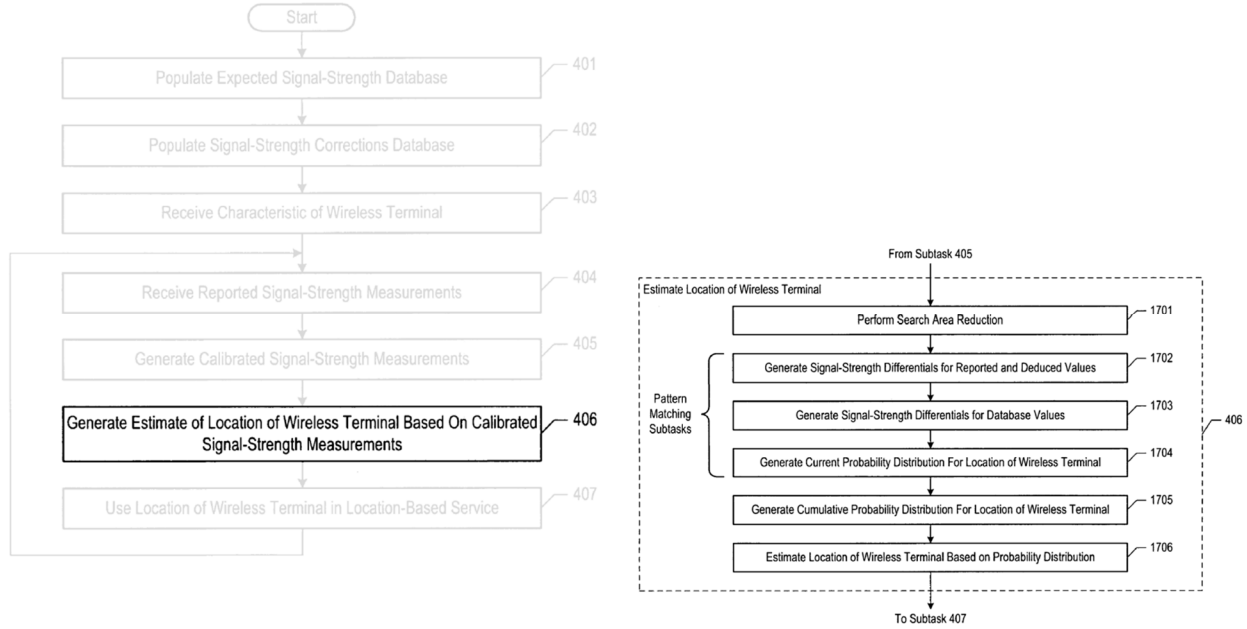
The purpose of task 405 is to correct—or compensate for the signal-strength measurement errors made by wireless terminal 201.” APPLE-1005, [0097], FIG.

4. By calibrating the signal strength measurements using the calibration function for the make and model of wireless terminal 201, Bhattacharya discloses [1.5].



77. Bhattacharya also discloses [1.5] in other ways. As previously discussed (Section IX.A), Bhattacharya’s location estimation technique involves comparing signal-strength differentials based on measurements collected by wireless terminal 201 against “a map or database that correlates locations to signal

strengths.” APPLE-1005, [0014]. This comparison is shown in task 406 of Bhattacharya’s Figure 4 (left) and involves several subtasks shown in Bhattacharya’s Figure 17 process (right):



78. Task 406 includes a set of pattern matching subtasks, including sets of signal-strength differentials for reported and expected data in subtasks 1702 and 1703, respectively. APPLE-1005, [0179]-[0188]. The “idea” behind using signal-strength differentials is to “ensure that ‘apples are compared with apples’ in subtask 1704...” *Id.*, [0187]. The following equation used to compute signal-strength differentials:

$$\Delta N(k,n) = N(k+1,n) - N(k,n) \quad (\text{Eq. 7})$$

wherein $k=1, 2, 3, \dots, m-1$, and $\Delta N(k,n)$ is the k th signal-strength measurement differential for Report n .

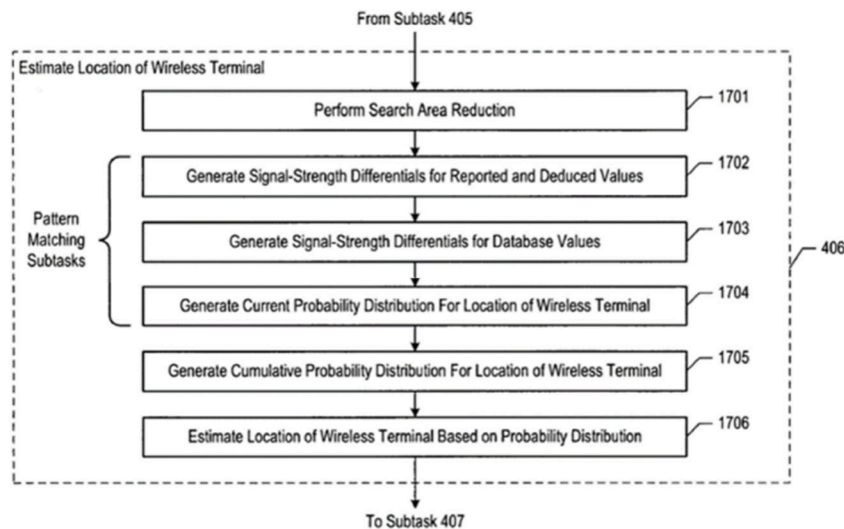
APPLE-1005, [0182]

79. The above-referenced computation techniques involve subtraction of two signal strength measurements, $N(k+1,n)$ and $N(k,n)$. For example, in equation 7 above, the signal measurement of $N(k+1,n)$ is modified by $N(k,n)$ to yield a ***“modified said observed network measurement data.”*** Indeed, Bhattacharya’s modification of ***“said observed network measurement data”*** is similar to an example provided by the ’494 patent of how network measurement (NM) data are modified. APPLE-1001, 5:15-19 (“NM data may also be modified to adjust the power levels received from the serving and/or neighboring cell (NC) base stations[,]” e.g., ***“differences in parameters*** between the serving cell and the NC may be calculated and the quantities used to ***modify*** the original NM data”) (emphasis added). Elsewhere, the ’494 patent specification describes that “[m]odifying the original NMR components” includes ***“subtracting*** or adding to existing NMR power components” using different examples of amounts, including “various known functions.” *Id.*, 6:63-7:10. The ’494 patent specification also provides non-limiting disclosure of several types of “NMR modification procedures.” *Id.*, 7:42-56.

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

80. As discussed for [1.5], Bhattacharya provides a location estimation technique where signal-strength data are compared against “a map or database that

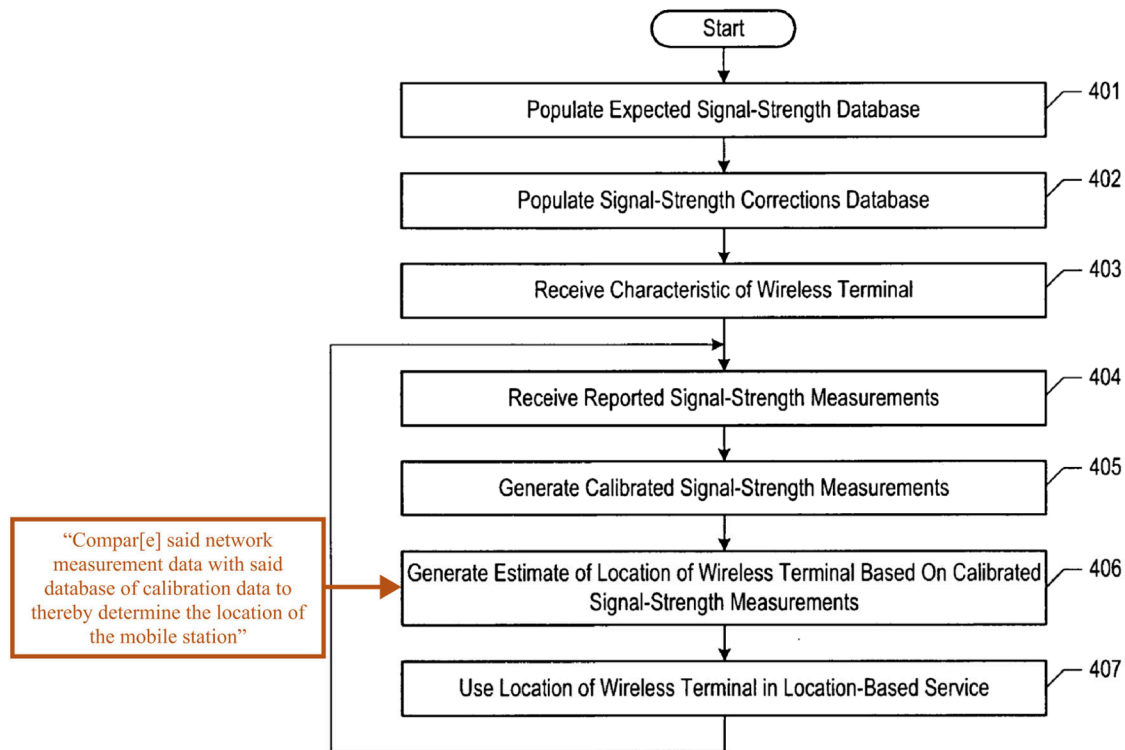
correlates locations to signal strengths.” APPLE-1005, [0014]. For example, in task 406 of Figure 4, the comparison is performed through several “pattern matching” subtasks shown in Bhattacharya’s Figure 17 process:



81. Subtasks 1702, 1703, 1704 involves pattern matching (“*comparing*”) signal-strength differentials (“*said modified network measurement data*”) in an SSMR and expected signal-strength differentials, which are generated based on data stored in the expected signal-strength database (“*said database of calibration data*”). See APPLE-1005, [0179]-[0189]. The comparison is used to generate “current probability distribution” based on “the most recently received reported signal-strength measurements” and “cumulative probability distribution” based on “all of the received signal-strength measurements.” *Id.*, [0190].

82. Further, the above-referenced pattern matching techniques are used to estimate a location of wireless terminal 201 (“*to determine the location of the*

mobile station”). Specifically, the system begins with “candidate locations that must be considered as the location for wireless terminal 201[,]” and “reduce[s] the number of candidate locations that must be processed” using “search area reduction,” which involves excluding candidate locations with probabilities “calculated to be very close to zero.” APPLE-1005, [0172]-[0173]. Use of the signal-strength differentials discussed above “ensure[s] that ‘apples are compared with apples,’” in other words, that the same types of values from reported data and calibration data are compared. *Id.*, [0187]. As noted above, the comparison is used to generate “current probability distribution” based on “the most recently received reported signal-strength measurements” and “cumulative probability distribution” based on “all of the received signal-strength measurements.” *Id.* Using both types of distributions enable location system 212 to “generate an estimate of the location of wireless terminal 201 that is more accurate than the estimate that is derivable from signal-strength measurements made at one time alone.” *Id.*, [0190].



APPLE-1005, FIG. 4 (annotated)

83. Location estimation in Bhattacharya and the '494 patent specification each involve the same type of data (signal strength values) and the same type of modification of such data (difference calculations). In the '494 patent specification, the “modified network measurement data” may be generated by computing “differences in parameters between the serving cell and the [neighboring cells],” e.g., “[i]f an original NMR received at the [position determining equipment 50] had the form $NMR1=[P1, P2, P3, TA1]$ ” where P1, P2, and P3 are base station power levels, then “the modified NMR may be represented by: $NMR_modified=[0, P1-P2, P1-P3, TA1]$.” APPLE-1001, 5:20-31. Bhattacharya

similarly describes generation of “signal-strength measurement differentials” between “different pairs of signal-strength measurements $\{N(1,n), \dots N(m,n)\}$.” APPLE-1005, [0182].

2. *Claim 2*

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

84. As discussed for [1.2], Bhattacharya’s expected signal-strength database (“*said database*”) is populated to store data representing expected signal-strength measurements (“*previously-gathered calibration data*”). APPLE-1005, [0085]-[0090], [0115]. The expected signal-strength database “correlates location to expected signal strength.” APPLE-1005, [0015]. For example, the database is “populated with the expected signal strengths of three signals at each location in geographic region 200.” *Id.*, [0085]. Each measurement is associated with “its expected signal strength at location x, y at time t.” *Id.*, [0086]. Since each expected signal-strength measurement are for a known location coordinate (e.g., x, y coordinates) when populated in the database, the locations associated with the location coordinates are “*one or more predetermined calibration points within said region.*”

3. *Claim 5*

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

85. As discussed for [1.2], Bhattacharya's expected signal-strength database is populated to store data representing expected signal strength measurements ("***previously-gathered calibration data***"). APPLE-1005, [0085]-[0090], [0115]. Further, since each expected signal-strength measurement has a known location coordinate (e.g., x, y coordinates) when populated in the database, each measurement ("***signal strength information***") is "***measured at a predetermined calibration point within said region.***" APPLE-1005, [0085], [0086].

86. Moreover, in one example described in Bhattacharya, expected signal strengths of three signals ("Signal 1," "Signal 2," "Signal 3") are broadcasted by respective base stations (base stations 202-1, 202-2, 202-3) also located at known locations within geographic region 200. APPLE-1005, [0086]. In this example, since expected signal-strength measurements are of signals transmitted by base stations at known locations within geographic region 200, each expected signal-strength measurement is of "***a signal transmitted from a known location within or in proximity to said region.***" *Id.*

4. *Claim 9*

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

87. As discussed for [1.2], Bhattacharya's expected signal-strength database is populated to store expected signal-strength measurements ("***previously-gathered calibration data***"). APPLE-1005, [0085]-[0090], [0115]. Further, the database is "populated with the expected signal strengths of three signals at each location in geographic region 200" such that that data stored in the database includes "Signal 1, Signal 2, and Signal 3." APPLE-1005, [0085].

88. Bhattacharya discusses the existence of a well-known location estimation technique in which "the location of a wireless terminal is estimated to be at the center of the cell in which the wireless terminal is located," and further indicates that this technique can be "inexpensively implemented in legacy systems." APPLE-1005, [0009]. Elsewhere, Bhattacharya indicates that embodiments of its invention are "ideally suited for use with legacy systems." Id., [0013]. Based on these disclosures, a POSITA would have understood that, in certain implementations of Bhattacharya, a serving base station is assigned to a single cell. APPLE-1009, 5:1-12 ("Those skilled in the art will appreciate that a cell is the area given radio coverage by one base transceiver station, or BTS"); APPLE-1006, [0239]. In such implementations, a POSITA would have found

understood that the wireless terminal 201 uses base station identification information (e.g., “base station identity code”) to identify the serving base station, and thus, the base station identification information is “information identifying a serving cell of a transmitter.” APPLE-1005, [0087]. For example, as a “GSM-compliant wireless terminal,” wireless terminal 201 would have received control channel signals sent by a base station, where the base station identification information includes a “cell identifier,” which denotes the unique identifier of a cell. APPLE-1012, 51-52; APPLE-1005, [0052]. Such control signals are used by mobile terminals to measure signal strength to various cells and determine which cell to camp on.

89. Figure 9 shows “the expected signal strength, $E(2, t=0)$, of Signal 2 at each location” in region 200. APPLE-1005, [0036]. Thus, since expected signal-strength values at each of the locations shown in Figure 9 are associated with the serving base station (base station 202-2), each expected signal-strength value represents a “*signal received at a predetermined calibration point.*” APPLE-1005, [0125].

5. *Claim 12*

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

90. See [1.2], *supra*. Bhattacharya's expected signal-strength database is populated to store expected signal-strength measurements ("**previously-gathered calibration data**"). APPLE-1005, [0085]-[0090], [0115]. In addition, it would have been understood by a POSITA that, in Bhattacharya, the examples of locations where expected signal-strength values are collected ("**said predetermined calibration point**") would have included indoor and outdoor ("**not located within a structure**") locations. APPLE-1005, [0055], [0057], [0058], [0063], FIG. 2, [0002] (explaining that base stations are "dispersed throughout [a] geographic area serviced by the system"), [0009] (explaining that accuracy of legacy location estimation systems was within several kilometers), [0010]. Because the expected signal-strength values are collected from various locations associated with locations of wireless terminals within a region that spans kilometers, such locations ("**said predetermined calibration point**") would have included points that are "not located within a structure."

6. *Claim 14*

91. Bhattacharya anticipates claim 14 in the same manner as I explained above for the corresponding claim 1 limitations listed in the table below.

Claim 1 Limitation	Corresponding Limitation
[1.1]	[14.1]
[1.2]	[14.2]
[1.4]	[14.5]
[1.5]	[14.6]
[1.6]	[14.7]

92. Features uniquely recited in claim 14 are addressed below.

[14.3] wherein said network includes a serving transmitter;

[14.4] collecting observed network measurement data including a first signal characteristic from said serving transmitter,

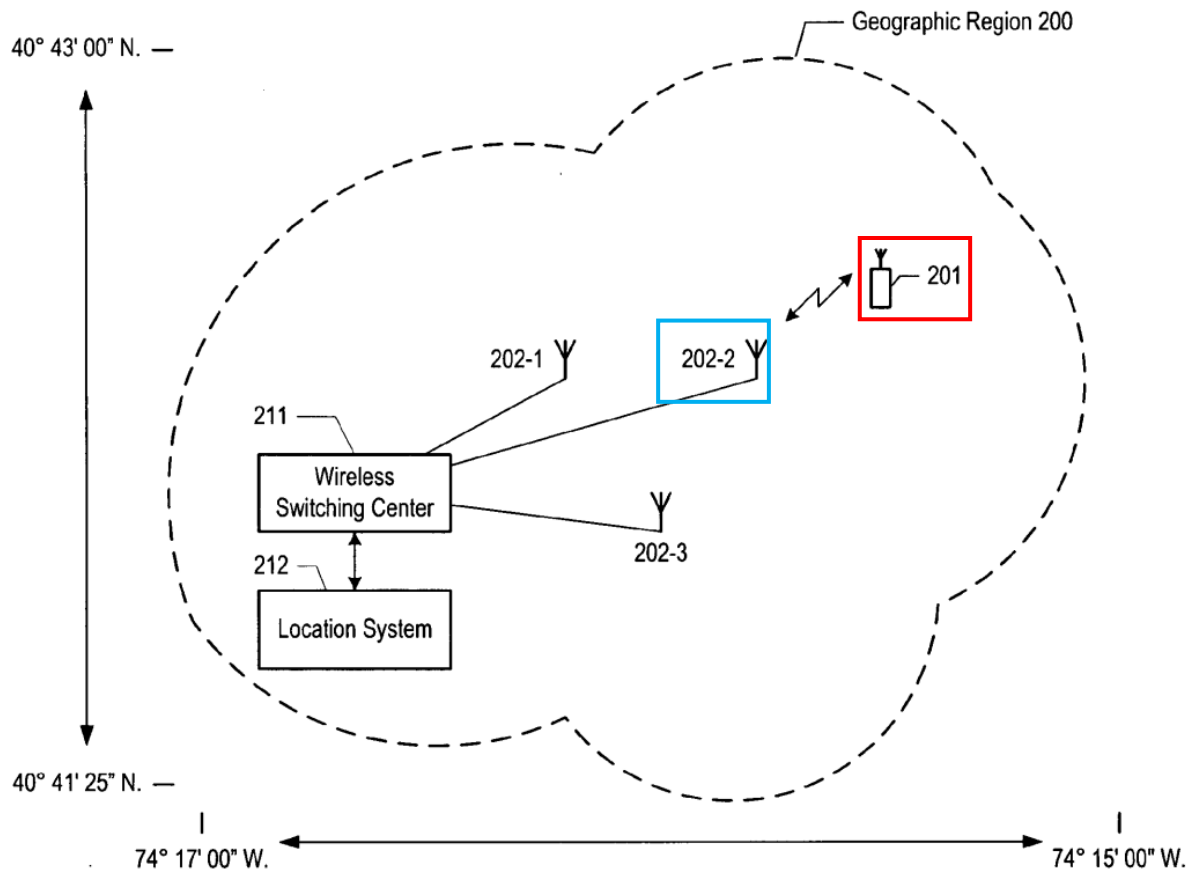
[14.6] modifying said observed network measurement data using said first signal characteristic; and

93. Claim 14 recites a method for determining a location of a mobile station that involves nearly identical steps as those recited in claim 1, but further recites additional features of “*first signal characteristic*” and “*serving transmitter.*” As discussed below, Bhattacharya discloses these additional features through the location estimation techniques discussed in Section X.A.

94. Bhattacharya provides a base station acting as a “*serving transmitter*” through examples of base station arrangements with a serving base station. In the arrangement shown in Bhattacharya’s Figure 1, “base station 102-2 *serves* wireless terminal 101” and therefore represents a serving base station for geographic region 100. APPLE-1005, [0003]. Further, Figure 2 (reproduced below) shows a similar arrangement of base stations in a geographic region 200 where “wireless terminal

201 is *serviced* by base station 202-2.” APPLE-1005, [0055]. Base station 202-2 (which coincides with base station 102-2 in a similar arrangement) represents a transmitter that includes “*serving cell*” in the exemplary network of geographic region 200.

Figure 2



95. As discussed for [1.3] and [1.4], wireless terminal 201 measures (“*collect[s]*”) signal-strengths measurements (“*observed network measurement data*”) included in an SSMR, such as “a tuple of reported signal-strength measurements $\{R(1,n), R(2,n), R(3,n)\}$.” APPLE-1005, [0091]. For example,

“R(2,n)” is “the nth reported signal-strength measurement of Signal 2 as measured by wireless terminal 201 at time t” where Signal 2 is the signal associated with base station 202-2. *Id.*; *see also id.*, [0086]. Thus, since “R(2,n)” is associated with base station 202-2 as the serving base station, “R(2,n)” is the “***first signal characteristic from said serving transmitter.***” Further, since signal-strength measurement values included in the SSMR (which includes “R(2,n)”) are used to generate signal-strength differentials, the generation (“***modifying***”) involves using “R(2,n)” to compute at least some of the signal-strength differentials (“***modifying...using said first signal characteristic***”). APPLE-1005, [0179].

7. *Claim 18*

[18] The method of claim 14 wherein said first signal characteristic is signal strength.

96. *See* [1.3], *supra*. As discussed for [14.3], the signal-strength measurements collected by wireless terminal 201 includes “R(2,n)” (“***said first signal characteristic***”). In this example, “R(2,n)” is a “signal-strength measurement of Signal 2,” and thus, is “***signal strength.***” APPLE-1005, [0091]-[0094], [0158]-[0160].

8. *Claim 19*

[19] The method of claim 18 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.

97. As discussed for [1.3] and [1.4], wireless terminal 201 measure (“*collect[s]*”) signal-strength measurements (“*observed network measurement data*”) included in an SSMR. The measurements include “a tuple of reported signal-strength measurements {R(1,n), R(2,n), R(3,n)}.” APPLE-1005, [0091]. In the SSMR, “R(1,n)” is “the nth reported signal-strength measurement of Signal 1 as measured by wireless terminal 201 at time t” where Signal 1 is the signal associated with base station 202-1. *Id.*; *see also id.*, [0086]. As explained for Claim 14 (Section X.A.7), base station 202-2 is an example of a serving transmitter, and thus, base stations 202-1 and 202-3 are each an example of a “*neighboring transmitter*.” APPLE-1005, [0003], [0055]. Thus, since “R(1,n)” is associated with a base station that acts as a neighboring transmitter, “R(1,n)” is the “*second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength*.” APPLE-1005, [0091]-[0094], [0158]-[0160].

9. *Claim 20*

[20] The method of claim 19 wherein the modifying of said calibration data uses a difference between said first and second signal characteristics.

98. As discussed for [1.6], Bhattacharya's location estimation technique involves "pattern matching" subtasks in which signal-strength differentials determined using SSMRs are compared to expected signal-strength differentials in the expected signal-strength database. APPLE-1005, [0179]-[0189]. Specifically, "expected signal-strength differentials" are computed "for all of the locations not excluded from consideration" in a prior search area reduction step. *Id.*, [0184]. Further, generation of expected signal-strength differentials is to "ensure that 'apples are compared with apples'" in the comparison of expected signal-strength values and reported signal-strength values in estimating the location of a wireless terminal. *Id.* Based on these disclosures, in at least some circumstances, expected signal-strength differentials are generated for comparison against signal-strength differentials computed from Signal 1 ("R(1,n)") and Signal 2 ("R(2,n)") such that generation of the expected signal-strength differentials ***"uses a difference between said first and second signal characteristics."***

10. *Claim 21*

[21] The method of claim 14 wherein said first signal characteristic is signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.

99. As discussed for Claim 14, base station 202-2 represents an example of a “***serving transmitter***” in the network of geographic region 200 since “wireless terminal 201 is serviced by base station 202-2.” APPLE-1005, [0003], [0055]. Further, signal-strength measurement, “R(2,n)” (or Signal 2) is associated with base station 202-2 and thereby the “***first signal characteristic***.” APPLE-1005, [0086]. Further, since “Signal 2 is the overhead control channel broadcast by base station 202-2,” “R(2,n)” (or Signal 2) is the “***signal strength of a control channel transmitted by said serving transmitter and received by said mobile station***.” *Id.*

11. *Claim 22*

[22] The method of claim 21 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.

100. As discussed for Claim 14, base station 202-2 is an example of a serving transmitter, and thus, base stations 202-1 and 202-3 are examples of a “***neighboring transmitter***.” APPLE-1005, [0003], [0055]. Further, signal-strength measurement, R(1,n) (or Signal 1) is associated with a base station 202-1 and thereby the “***second signal characteristic***.” APPLE-1005, [0086]. Further, since

“Signal 1 is the control channel broadcast by base station 202-1,” R(1,n) (or Signal 1) is the collected “*signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.*” *Id.*

12. *Other Claims - Claim 16*

101. Bhattacharya anticipates claim 16 in the same manner as explained above for the corresponding claims listed in the table below.

Claim	Corresponding Claim	Corresponding Evidence
[16]	[12]	APPLE-1005, [0055], [0057], [0058], [0063], FIG. 2

XI. [GROUND 1B] – BHATTACHARYA AND SPAIN MAKES CLAIMS 1-5, 9, 11, 12, 14-16, AND 18-22 OBVIOUS

A. Combination of Bhattacharya and Spain

102. As discussed in Section IX.A, Bhattacharya emphasizes the importance of leveraging the expected signal-strength functions that are “a function of time” to account for time-dependent changes based on “atmospheric and meteorological conditions.” *Id.*, [0114]. It further emphasizes the significance of “pattern matching the calibrated signal-strength measurements {S(1,n), S(2,n), S(3,n)} against the expected signal-strength functions E(1,x,y,t), E(2,x,y,t), and E(3,x,y,t) that correspond in time to when the signal-strength measurements underlying {R(1,n), R(2,n), R(3,n)} are based.” *Id.*, [0127]. Yet Bhattacharya does not specifically address how its expected signal-strength database is populated to

account for time-dependent changes based on “atmospheric and meteorological conditions.” Bhattacharya also does not specifically define the terms “time” and “conditions.” The absence of such detail would have led a POSITA looking to implement Bhattacharya’s teachings to look beyond its disclosure to well-known techniques—including those published by the same inventors or the same assignee relatively close in time to Bhattacharya—for generating and using expected values to account for time-dependent changes based on atmospheric and meteorological conditions.

103. A POSITA would have discovered Spain, which is a publication of a U.S. application filed on 5/22/2006 by the same original applicant as Bhattacharya (Polaris Wireless, Inc.) and multiple overlapping inventors (David Spain, Martin Feuerstein). APPLE-1005, 1; APPLE-1006, 1. Like Bhattacharya, Spain describes techniques for estimating the location of a wireless terminal, but, additionally, offers implementation details on expected values stored in a database and used for pattern matching in location estimation. APPLE-1006, [0006], [0072], [0076]. Spain also offers specific examples of “calendrical time” and “environmental conditions,” each of which are relevant to the “time” and “conditions” terms referenced in Bhattacharya. *Compare* APPLE-1005, [0114], [0127] *and* APPLE-1006, [0035].

104. In combining Bhattacharya and Spain, a POSITA would have found obvious that Bhattacharya's expected signal-strength measurements (stored in an expected signal-strength database) correspond to Spain's expected values (stored in location-trait database 313). Bhattacharya's database is populated using expected signal strengths using expected signal-strength functions that relate signal strength, location (x, y), and time (t). APPLE-1005, [0086], [0115]. Likewise, Spain's location-trait database 313 is populated using expected values for traits of a location, which interrelate among others, signal strength, location (b), and time (t). APPLE-1006, [0076]. Further, the expected signal-strength functions used by the Bhattacharya system are determined through theoretical models and/or empirical measurements. APPLE-1005, [0120]. Expected values of traits used by the Spain system are similarly determined through theoretical models and/or empirical measurements. APPLE-1006, [0126]-[0128].

105. A POSITA would have also understood and found obvious that the natural implementation of the database provided by Bhattacharya-Spain is one in which expected values are collected and populated in the database as a calibration data gathering step that occurs prior to wireless terminals later measuring values for comparison to this previously gathered calibration data for location estimation. Notably, such a calibration data gathering step is consistent with the teachings of Bhattacharya and Spain. Bhattacharya teaches that generating expected values is

“generally complex and potentially expensive, and it is, performed only when necessary.” APPLE-1005, [0087]. Spain likewise expresses a concern that “[t]he process for generating [a] multi-dimensional probability distribution can be computationally intensive” and “when the number of locations that must be considered is large, the process can often take too long.” APPLE-1006, [0215]. A POSITA, would have recognized that prior generation of expected values and storage of those values in the database (as distinguished from generating these values at the same time point as measurement by a wireless terminal of values for estimating its location) ensures that the location server is not slowed down in performing location estimation by having to engage in a laborious and computationally-intensive process of generating and storing the expected values each and every time a location estimate is desired for a given wireless terminal.

106. Spain’s express teachings would have further led a POSITA to implement a system that generates expected values and stores those values in Bhattacharya’s database as a pre-processing step that occurs prior to measurement of values by wireless terminals for comparison to the stored expected values as part of location estimation. For example, Spain’s location-trait database 313 stores “environmental conditions” as one of the traits associated with each location. APPLE-1006, [0076], [0086], [0102]. A POSITA would have recognized that if Spain contemplated generating expected values at roughly the same time point as

values are measured by the wireless terminal for estimating its location, such a configuration would have obviated the need for location-trait database 313 to store expected values as a function of environmental conditions since the correspondence in measurement times would have led to substantially the same environmental conditions associated with each measurement (e.g., if it is raining in a given location, both the expected values and the measured values already account for the rain because they are measured at the same time and are equally impacted by the rain, making it unnecessary to expressly account for rain as a separate parameter when comparing the two). Spain's location estimation technique instead accounts for environmental conditions in that the "set of measurements" provided by wireless terminal 201 to location server 214 includes "an indication of the environmental conditions, N," which accounts for environment as a separate parameter. The location server 214 uses this information to identify appropriate expected values stored in the location-trait database 313 for comparison. *Id.*, [0202]. By accounting for environment as a separate parameter, Spain's disclosure contemplates gathering and storage of expected values prior to any measurement being performed by a wireless terminal for estimating its location.

107. Spain describes that "a drive-test regimen is developed that periodically makes empirical measurements throughout geographic region 220 with highly-accurate equipment to ensure the accuracy, freshness, and

completeness of the information contained in Location-Trait Database 313...”

APPLE-1006, [0173]. A natural implementation of this disclosure is that “drive-test regimen” enables use of “highly-accurate equipment” for calibration, i.e., the highly-accurate equipment periodically collects empirical measurements representing expected values, which are then used to update location-trait database 313.

108. A POSITA would have reasonably expected to succeed in combining Bhattacharya and Spain since its implementation would have required only routine knowledge well within the skill of a POSITA prior to the earliest effective filing date. Bhattacharya describes generation of expected signal-strength functions as “well-known,” confirming that leveraging Spain’s teachings of its location-trait database 313 to implement Bhattacharya would have been capable of being performed by a POSITA without invention. APPLE-1005, [0112]. In this manner, the Bhattacharya-Spain combination would have merely involved combining prior art elements according to known methods to yield predictable results.

109. Furthermore, the elements of Bhattacharya-Spain would each perform functions they had been known to perform prior to the combination—a location system would apply functions interrelating time, location, and environmental conditions to generate expected signal-strength values for pattern matching against reported values for estimating the location of a wireless terminal (as described in

Bhattacharya and Spain). APPLE-1005, [0112]-[0117]; APPLE-1006, [0035]. A POSITA would have naturally expected success when incorporating Spain's teachings into Bhattacharya, as described above. Indeed, given the similarities of inventors, assignee, and described subject matter, the combination would also have been predictable given that a POSITA would have looked to similar systems to better understanding the teachings and implementations of Bhattacharya.

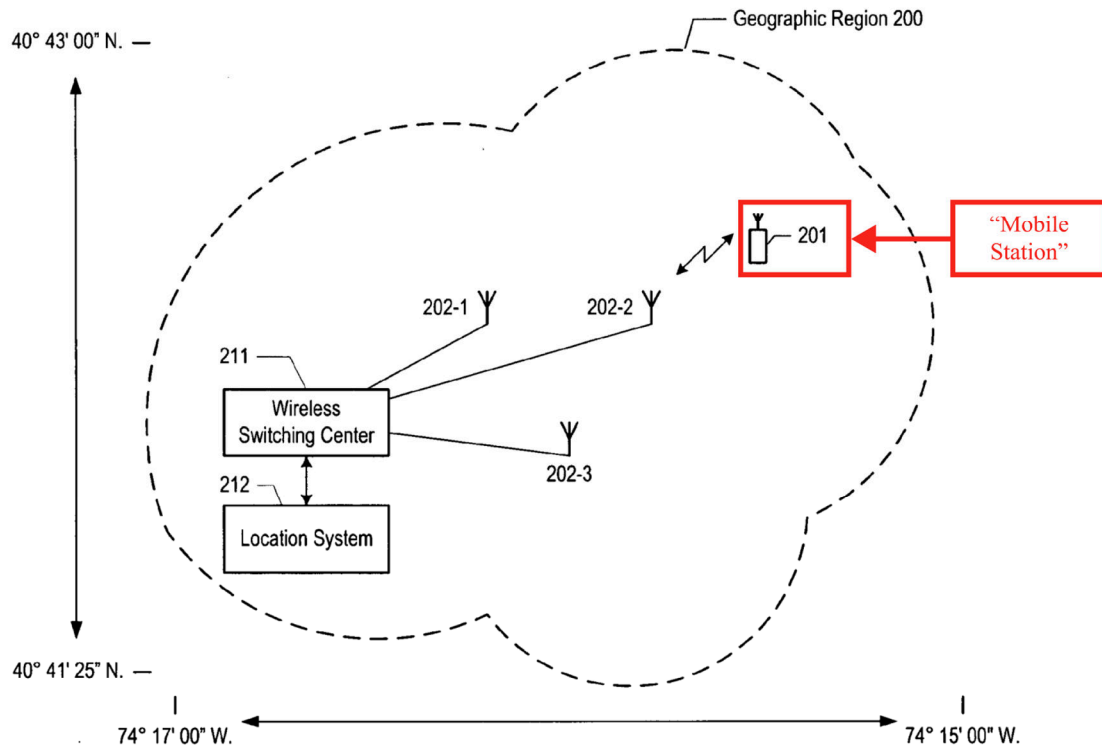
B. Analysis

1. *Claim 1*

[1.1] A method for determining a location of a mobile station, comprising:

110. Even if the preamble were properly limiting (it is not), Bhattacharya-Spain renders it obvious. As shown in Bhattacharya's Figure 2 (annotated below), Bhattacharya-Spain provides a combined system that includes a wireless terminal ("*mobile station*"). APPLE-1005, [0056] ; *see supra* Section X.A.1.

Figure 2



111. As discussed below, the combined system implements a method that ***“determine[s] a location of the wireless terminal.”***

112. Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [1.1] in Section X.A.1, disclose aspects of this limitation. APPLE-1005, Abstract, FIGs. 2, 4.

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

113. Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [1.2] in Section X.A1, disclose aspects of this limitation. APPLE-1005, [0115], FIGs. 2, 4.

114. For example, Bhattacharya-Spain would have operated within geographic region 200 (“*predetermined region*”) and provided wireless telecommunications services through a network (“*wireless network*”) associated with region 200. APPLE-1005, [0051]. The combination would have provided an expected signal-strength database (“*database*”) that is populated to store various types of data representing expected values (“*calibration data*”). APPLE-1005, [0085]-[0087].

115. A POSITA would have found it obvious that data representing expected values that is stored in a database provided by Bhattacharya-Spain is an example of information based on prior network measurements. As discussed in Sections IX.B and XI.A, Spain indicates scenarios in which at least some of the expected values already exist in the database (i.e., are preexisting calibration data) when values are measured by a wireless terminal at a later time point. APPLE-1006, [0070], [0173], [0174].

116. Moreover, based on disclosures in Bhattacharya and Spain, a POSITA would have understood and found obvious that data representing expected values stored in the expected signal-strength database represents “*previously-gathered*” data. APPLE-1005, [0089]-[0090]. As explained in Sections IX.A-B and XI.A, a POSITA would have implemented Bhattacharya-Spain such that expected values are collected and populated in a database as a calibration data gathering step that

occurs prior to wireless terminals later measuring values for comparison to this previously gathered calibration data for location estimation. APPLE-1005, [0087]; APPLE-1006, [0105], [0215]. Prior generation of expected values and storage of those values in the database ensures that the location server is not slowed down in performing location estimation by having to engage in a laborious and computationally-intensive process of generating and storing the expected values each and every time a location estimate is desired for a given wireless terminal.

117. Further, based on Spain, a POSITA would have also implemented the database of Bhattacharya-Spain to store “environmental conditions” as one of the traits associated with each location. APPLE-1006, [0076], [0086], [0102], [0105]. Spain’s location estimation technique accounts for environmental conditions in that a “set of measurements” provided by wireless terminal 201 to location server 214 includes “an indication of the environmental conditions, N,” thereby expressly accounting for environment as a separate parameter. The location server 214 uses this information to identify appropriate expected values stored in the location-trait database 313 for comparison. *Id.*, [0202]. By accounting for environment as a separate parameter, Spain’s disclosure contemplates gathering and storage of expected values prior to any measurement being performed by a wireless terminal for estimating its location. Thus, the Bhattacharya-Spain database is populated with “*previously-gathered calibration data*” insofar as the stored data was

collected and populated in the database during a pre-processing step that occurs prior to measurement of values by wireless terminals for comparison to the stored expected values as part of location estimation.

118. Spain's maintenance techniques for location-trait database 313 further indicate scenarios in which at least some of expected values already exist in the database (i.e., are preexisting calibration data) at time points when values are measured by a wireless terminal. APPLE-1006, [0070], [0105], [0173], [0174]. An exemplary configuration of such a maintenance technique is one in which existing content in location-trait database 313 is appended with newly collected data such that the preexisting calibration data (e.g., data collected during a prior calibration operation) remains in the database for a specified time period. *Id.*, [0070]. In such scenarios, the database is populated with “*previously-gathered calibration data*” insofar as data previously gathered for location estimations performed at prior time points are available in the database (i.e., are preexisting calibration data) at a later time point when values are measured by a wireless terminal.

119. Finally, implementation of Bhattacharya-Spain to collect and store expected values in a database prior to a wireless terminal later measuring values for comparison for location estimation, as discussed above, is consistent with disclosure in the '494 patent specification corresponding to the “previously-gathered calibration data.” In the '494 patent specification, “calibration data is

typically collected in an outdoor environment” for “greater ease of performing automated calibration procedures.” APPLE-1001, 1:27-38. Further, “calibration data may be obtained from data collection devices during field test operations, and/or from [mobile stations] or other communication devices within the general area of the [non-uniform grid points.” *Id.*, 4:1-14. Like the examples of calibration data described in the ’494 patent specification, expected signal-strength measurements in Bhattacharya-Spain may be “generated by taking empirical measurements at various locations.” APPLE-1006, [0105], [0119].

120. By the Critical Date, a POSITA would have known that least one method of collecting the empirical measurements described by Bhattacharya-Spain would have been to transport testing devices around the geographic region 200 and measure the signal strength for each of the three signals received from the three base stations (202-1, 202-2, and 202-3) and the geographic location of the testing device (e.g., using a GPS receiver connected to the testing device) in order to determine the (x,y) associated with each of the three signals. *See, e.g.*, APPLE-1001, 5:12-27, 5:50-60, 7:6-21. A POSITA would have also known that one method of generating expected signal strength for a grid point would have been to collect multiple empirical measurements within the grid square surrounding the grid point and average the multiple empirical measurements. *Id.*, APPLE-1011, 7:28-44. By averaging multiple empirical measurements within the grid square

surrounding the grid point, a POSITA would have understood or at least found it obvious that some of the effects of fast fading could be removed. *See, e.g., id.*, 7:50-56. In this regard, a POSITA would have understood or at least found it obvious that the expected signal-strength functions $\{E(1,x,y,t), E(2,x,y,t), \text{ and } E(3,x,y,t)\}$ for a given grid point within the geographic region 200 may represent an average of calibration data from multiple locations within the grid square, and not simply represent the storage of the calibration data itself. *See id.*

[1.3] collecting observed network measurement data;

121. Bhattacharya-Spain provides a location estimation technique in which a wireless terminal measures (“*collect[s]*”) signal-strength measurements (“*observed network measurement data*”) included in a SSMR. APPLE-1005, [0091]-[0094], [0158]-[0160]. Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [1.3] in Section X.A.1, disclose aspects of this limitation. APPLE-1005, [0091]-[0094], [0158]-[0160].

[1.4] the observed network measurement data collected by the mobile station and transmitted to the network or collected by the network;

122. Bhattacharya-Spain render obvious [1.4] for the same reasons described above in Ground 1A. *See* Section X.A.1.

123. As discussed for [1.3], in Bhattacharya-Spain, signal-strength measurements (“*observed network measurement data*”) are included in the SSMR provided by a wireless terminal to a location system (“*transmitted to the*

network”). APPLE-1005, [0091]. For example, the signal-strength measurements include “a tuple of reported signal-strength measurements $R(1,n)$, $R(2,n)$, $R(3,n)$,” where “ $R(1,n)$ ” is “signal-strength measurement of Signal 1 as measured by wireless terminal 201 at time t ,” “ $R(2,n)$ ” is “signal-strength measurement of Signal 2 as measured by wireless terminal 201 at time t ,” and “ $R(3,n)$ is the n th reported signal-strength measurement of Signal 3 as measured by wireless terminal 201 at time t .” *Id.*, [0092]-[0094].

[1.5] *modifying said observed network measurement data; and*

124. Bhattacharya-Spain provides a location estimation technique in which received signal strength information is calibrated and sets of signal-strength differentials are generated for reported and expected data to “ensure that ‘apples are compared with apples’...” APPLE-1005, [0181]-[0188]. A POSITA would have understood and found obvious that the subtraction operation to obtain signal-strength differentials involves “*modifying said observed network measurement data*”. APPLE-1005, [0179]. Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [1.5] in Section X.A.1, disclose aspects of this limitation. APPLE-1005, [0014], [0179]-[0188], FIGs. 4, 17; APPLE-1001, 5:15-19, 6:63-7:10, 7:42-56.

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

125. Bhattacharya-Spain would have provided a location estimation technique in which signal-strength data are compared against “a map or database that correlates locations to signal strengths.” APPLE-1005, [0014]. This involves pattern matching (“***comparing***”) signal-strength differentials (“***said modified network measurement data***”) and expected signal-strength differentials, which are generated based on data stored in the expected signal-strength database (“***said database of calibration data***”). See APPLE-1005, [0179]-[0189]. The pattern matching techniques are used to estimate the location of wireless terminal 201 (“***determine the location of the mobile station***”). Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [1.6] in Section X.A.1, disclose aspects of this limitation. *Id.*, [0172]-[0173], [0187], [0190], FIG. 4.

2. Claim 2

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

126. As described above in Section XI.B.1.[1.2], Bhattacharya-Spain would have provided a database (“***said database***”) that a POSITA would have found obvious, based on Spain, to implement to store data representing signal-strength measurements collected at a pre-processing or prior measurement step

(**“previously-gathered calibration data”**). APPLE-1005, [0085]-[0090], [0115]; APPLE-1006, [0006], [0070], [0072], [0076]. As discussed in Section IX.B, Spain discloses that “a drive-test regimen is developed that periodically makes empirical measurements throughout geographic region 220 with highly-accurate equipment to ensure the accuracy, freshness, and completeness of the information contained in Location-Trait Database 313...” APPLE-1006, [0173]. A natural implementation of this disclosure is that “drive-test regimen” enables use of “highly-accurate equipment” for calibration, i.e., the highly accurate equipment periodically collects empirical measurements representing expected values, which are then used to update location-trait database 313. Since each expected signal-strength measurement has a known location coordinate (e.g., x, y coordinates) when populated in the database, the locations associated with the location coordinates are **“one or more predetermined calibration points within said region.”**

Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed for [2] in Section X.A.2, disclose features recited by this claim. APPLE-1005, [0015], [0066], [0085]-[0090], [0115].

3. *Claim 3*

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

127. As described in the '494 patent specification, a term “***non-uniform grid point***” (which is recited in claim 3) can “represent the signal characteristics and/or calibration data over a given region.” APPLE-1001, 3:57-67.²

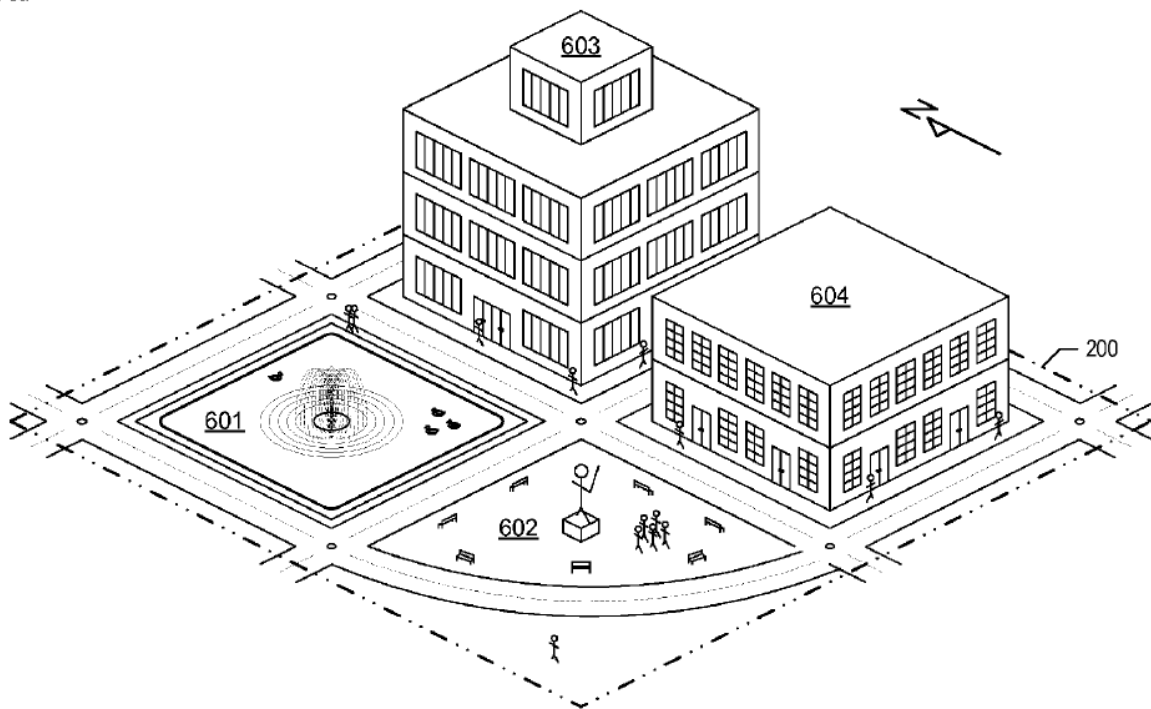
Bhattacharya-Spain renders this feature obvious through techniques in Spain for partitioning in a geographic region. Specifically, a location system of Bhattacharya-Spain includes requisite hardware for “populating, amending, using, and managing Location-Trait Database 313.” APPLE-1006, [0058]. Location-Trait Database 313 is “a database that maps each of a plurality of locations to one or more expected traits associated with a wireless terminal at that location.” *Id.*, [0066]. Further, in generating the Location-Trait Database 313, the location system partitions a geographic region 220 “into B(T,N) locations.” *Id.*, [0072]. Thus, expected values for partitioned locations are combined into the Location-

² This portion of the '494 patent specification also states that “[a]s illustrated in FIG. 1, a set of NUGs (NUG1, NUG2 and NUG3) are shown as being a part of a larger geographical region (R),” but these described features are absent from Figure 1.

Trait Database 313 (“*combin[ed] to form said previously-gathered calibration data at one or more predetermined calibration points*”).

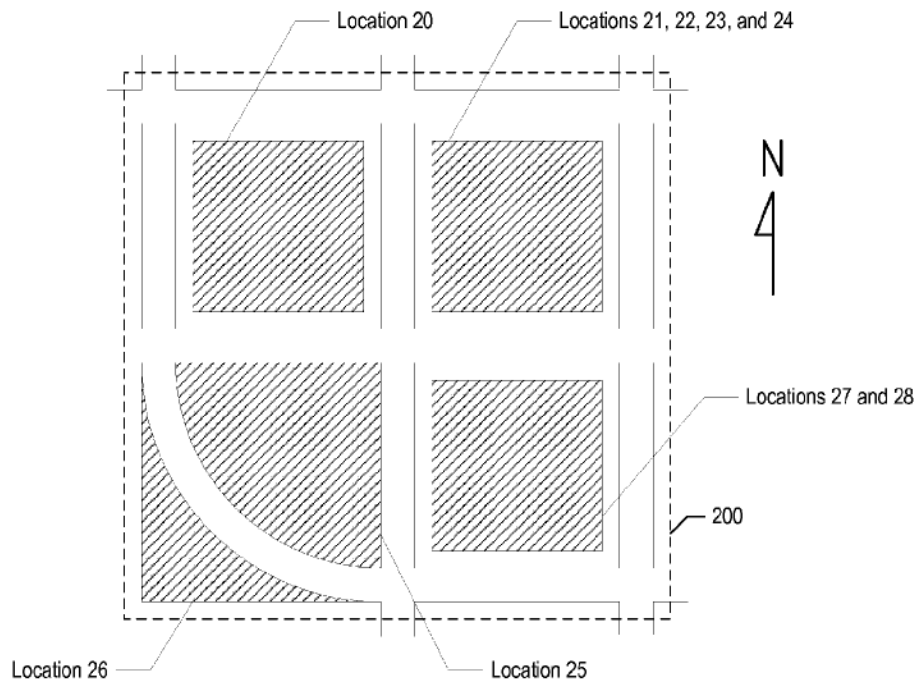
128. For example, Spain’s Figure 6A (below) depicts “an isometric drawing of geographic region 220.” APPLE-1006, [0098]. Note that Spain’s FIGS. 6A and 6E (also below) include a typographical error in that label “200” should be “220.”

Figure 6a



129. Geographic region 220 includes multiple locations, including “water fountain 601, park 602, four-story building 603, two-story building 604,” among others. APPLE-1006, [0098]. Region 220 can be partitioned into “any number of

locations of any size and shape.” *Id.*, [0099]. Locations 20-26 of geographic region 220 are shown in Figure 6E below:



130. As noted in Section IX.B, in Spain, each location is described by various information, e.g., “unique identifier,” and “coordinates” that “define its scope (e.g., position, area, volume, etc.” APPLE-1006, [0076]-[0082]. Further, in the Figure 6E example, locations 20, 25, and 26 have different shapes and sizes, and represent different areas of region 220. Thus, in this example, region 220 is partitioned such that the locations represent “*one or more non-uniform grid points within said region.*”

131. As described in Section XI.B.1. [1.2], Bhattacharya-Spain would have provided a database and a POSITA would have found obvious, based on Spain, to

implement the database to be populated with data representing expected signal-strength measurements collected at a pre-processing or prior measurement step (“*previously-gathered calibration data*”). APPLE-1005, [0085]-[0090], [0115]; APPLE-1006, [0006], [0070]. Since the database also specifies an “expected value $E(b, T, N, W, Q)$ for each trait, Q , when wireless terminal W is at location b at calendrical time T given environmental conditions, N ” for each location, the data stored in the database is “*combined*” from expected values at each location (“*one or more predetermined calibration points*”). *Id.* As another example, a POSITA would have known that, in populating an expected signal-strength database, Bhattacharya-Spain would have been configured to aggregate expected values associated with a geographic region. In some embodiments in Bhattacharya, “expected signal strength at each location is generated by taking empirical measurements at various locations and by interpolating for the locations in between the sampled locations.” APPLE-1005, [0119]. In such embodiments, a POSITA would have understood and found obvious that interpolation of empirical measurements of expected signal-strength values involves combining data for locations within the region. *Id.*

4. *Claim 5*

[5] *The method of claim 1 wherein said previously-gathered calibration data includes signal strength information measured at a predetermined calibration*

point within said region for a signal transmitted from a known location within or in proximity to said region.

132. Bhattacharya-Spain renders [5] obvious for the same reasons described above in Ground 1A. *See* Section X.A.3.

133. For example, Bhattacharya-Spain would have provided an expected signal-strength database that a POSITA would have found obvious to implement to store data representing expected values collected at a pre-processing step (“***previously-gathered calibration data***”). APPLE-1005, [0085]-[0090], [0115]. Further, since each expected signal-strength measurement has a known location coordinate (e.g., x, y coordinates) when populated in the database, each measurement (“***signal strength information***”) is “***measured at a predetermined calibration point.***” APPLE-1005, [0085].

134. In one example described in Bhattacharya, expected signal strengths of three signals (“Signal 1,” “Signal 2,” “Signal 3”) are broadcasted by respective base stations (base stations 202-1, 202-2, 202-3) also located at known locations within geographic region 200. APPLE-1005, [0086]. In this example, since expected signal-strength measurements are of signals transmitted by base stations at known locations within geographic region 200, each expected signal-strength measurement is of “***a signal transmitted from a known location within or in proximity to said region.***” *Id.*

5. *Claim 9*

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

135. Bhattacharya-Spain render [9] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.4.

136. For example, Bhattacharya-Spain would have provided a database that a POSITA would have found obvious, based on Spain, to implement to store data representing expected values (“***previously-gathered calibration data***”). APPLE-1005, [0085]-[0090], [0115]; APPLE-1006, [0006], [0070], [0072], [0076].

137. Bhattacharya discusses the existence of a well-known location estimation technique in which “the location of a wireless terminal is estimated to be at the center of the cell in which the wireless terminal is located,” and further indicates that this technique can be “inexpensively implemented in legacy systems.” APPLE-1005, [0009]. Elsewhere, Bhattacharya indicates that embodiments of its invention are “ideally suited for use with legacy systems.” *Id.*, [0013]. A POSITA would have understood and found obvious that, in certain implementations of Bhattacharya-Spain, a serving base station is assigned to a single cell. APPLE-1009, 5:1-12 (“Those skilled in the art will appreciate that a cell is the area given radio coverage by one base transceiver station, or BTS”); APPLE-1006, [0239]. In such implementations, a POSITA would have found

obvious that the Bhattacharya-Spain uses base station identification information (e.g., “base station identity code”) to identify the serving base station, and thus, the base station identification information is “information identifying a serving cell of a transmitter”). APPLE-1005, [0087]. For example, as a “GSM-compliant wireless terminal,” wireless terminal 201 would have received control channel signals sent by a base station, where the base station identification information includes a “cell identifier,” which denotes the unique identifier of a cell. APPLE-1012, 51-52; APPLE-1005, [0052]. Such control signals are used by mobile terminals to measure signal strength to various cells and determine which cell to camp on.

138. Bhattacharya’s Figure 9 also shows “the expected signal strength, $E(2, t=0)$, of Signal 2 at each location” in region 200. APPLE-1005, [0036]. Thus, since expected signal-strength values at each of the locations shown in Figure 9 are associated with the serving base station (base station 202-2), each expected signal-strength value represents a “***signal received at a predetermined calibration point.***” APPLE-1005, [0125].

139. Additionally, since expected signal-strength values at each of the location shown in Figure 9 are associated with the serving base station (base station 202-2), each expected signal-strength value represents a “***signal received at a predetermined calibration point.***” APPLE-1005, [0125]. Bhattacharya-Spain would have also incorporated the teachings of Bhattacharya, which, as discussed

for [9] in Section X.A.4, disclose features recited by this claim. APPLE-1005, [0003], [0036], [0085].

6. *Claim 11*

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

140. See Sections.X.A.1.[1.2] and XI.B.1.[1.2]. In Bhattacharya-Spain, an expected signal-strength database is populated to store expected values collected at a pre-processing or prior measurement step (“***previously-gathered calibration data***”). APPLE-1005, [0085]-[0090], [0115]. In Spain, examples of expected values include values for various traits of signals measured by a wireless terminal, such as “expected received delay spread,” “expected received relative arrival times,” “expected received relative arrival times,” and “expected round-trip time,” and “handover state” of a wireless terminal. APPLE-1006, [0103]-[0116]. A POSITA would have understood and found obvious that expected values of Bhattacharya-Spain includes “***information regarding a state of said wireless network***.” The examples of expected values in Bhattacharya-Spain coincide with examples of calibration data described in the ’494 patent specification, such as “round trip time, time difference of arrival.” APPLE-1001, 1:28-39.

7. *Claim 12*

[12] The method of claim 1 wherein said previously-gathered calibration data includes calibration data gathered at a predetermined calibration point within

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

141. Bhattacharya-Spain renders [12] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.5; *see also* Sections.X.A.1.[1.2] and XI.B.1.[1.2].

142. In Bhattacharya-Spain, an expected signal-strength database is populated to store expected signal-strength measurements (“***previously-gathered calibration data***”). APPLE-1005, [0085]-[0090], [0115]. The examples of locations where expected signal-strength values are collected (“***said predetermined calibration point***”) are outdoors, and thus, “***not located within a structure.***” APPLE-1005, [0055], [0057], [0058], [0063], FIG. 2.

8. *Claim 14*

143. Bhattacharya-Spain renders claim 14 obvious in the same manner as explained above for the corresponding claim 1 limitations listed in the table below.

Claim 1 Limitation	Corresponding Limitations
[1.1]	[14.1]
[1.2]	[14.2]
[1.4]	[14.5]
[1.5]	[14.6]
[1.6]	[14.7]

144. Features uniquely recited in claim 14 are addressed below.

[14.3] wherein said network includes a serving transmitter;

[14.4] collecting observed network measurement data including a first signal characteristic from said serving transmitter,

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

145. As discussed in Section X.A.6 (addressing Claim 14 in Ground 1A), claim 14 recites a method for determining a location of a mobile station that involves nearly identical steps as those recited in claim 1, but further recites additional features of “***first signal characteristic***” and “***serving transmitter.***” As discussed below, Bhattacharya-Spain renders these additional features obvious through the location estimation techniques discussed in Section XI.A.

146. In particular, Bhattacharya-Spain provides a base station acting as a “***serving transmitter.***” APPLE-1005, [0003], [0055]. A POSITA would have found obvious that base station 202-2 represents a transmitter that includes “***serving cell***” in the exemplary network of geographic region 200. Further, as discussed for [1.3], in Bhattacharya-Spain, a wireless terminal measures (“***collect[s]***”) signal-strength measurements (“***observed network measurement data***”) included in an SSMR. The measurements include “a tuple of reported signal-strength measurements {R(1,n), R(2,n), R(3,n)}.” APPLE-1005, [0091]. Since R(2,n) is associated with base station 202-2 (the serving base station), R(2,n) is the “***first signal characteristic from said serving transmitter.***” Reported signal-strength

measurement values included in the SSMR (which includes “R(2,n)”) are used to generate signal-strength differentials, and thus, their generation (“*modifying*”) involves using “R(2,n)” to compute at least some of the signal-strength differentials (“*modifying...using said first signal characteristic*”). APPLE-1005, [0179].

9. *Claim 18*

[18] The method of claim 14 wherein said first signal characteristic is signal strength.

147. Bhattacharya-Spain render [18] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.7.

148. For example, as noted in Sections X.A.6.[14.3] and XI.B.8.[14.3], the signal-strength measurements collected by the Bhattacharya-Spain terminal includes “R(2,n)” (“*said first signal characteristic*”). In this example, “R(2,n)” is a “signal-strength measurement of Signal 2,” and thus, is “*signal strength*.” APPLE-1005, [0091]-[0094], [0158]-[0160].

10. *Claim 19*

[19] The method of claim 18 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.

149. Bhattacharya-Spain render [19] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.8.

150. For example, as noted above in Sections XI.B.1.[1.3]-[1.4] and Section X.A.1.[1.3]-[1.4], the Bhattacharya-Spain terminal measures (“*collect[s]*”) signal-strength measurements (“*observed network measurement data*”) included in an SSMR. The measurements include “a tuple of reported signal-strength measurements {R(1,n), R(2,n), R(3,n)}.” APPLE-1005, [0091]. In the SSMR, “R(1,n)” is “the nth reported signal-strength measurement of Signal 1 as measured by wireless terminal 201 at time t” where Signal 1 is the signal associated with base station 202-1. *Id.*; *see also id.*, [0086]. As explained for Claim 14 (Section XI.B.8), base station 202-2 is an example of a serving transmitter, and thus, base stations 202-1 and 202-3 are each an example of a “*neighboring transmitter.*” APPLE-1005, [0003], [0055]. Thus, since R(1,n) is associated with a base station that acts as a neighboring transmitter, R(1,n) is the “*second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength.*” APPLE-1005, [0091]-[0094], [0158]-[0160].

11. *Claim 20*

[20] The method of claim 19 wherein the modifying of said calibration data uses a difference between said first and second signal characteristics.

151. Bhattacharya-Spain renders obvious [20] for the same reasons discussed above in Ground 1A. *See* Section X.A.9.

152. For example, as noted above in Sections XI.B.1.[1.6] and X.A.1.[1.6], Bhattacharya’s location estimation technique involves “pattern matching” subtasks

in which signal-strength differentials determined using SSMRs are compared to expected signal-strength differentials in the expected signal-strength database. APPLE-1005, [0179]-[0189]. Specifically, “expected signal-strength differentials” are computed “for all of the locations not excluded from consideration” in a prior search area reduction step. *Id.*, [0184]. Further, generation of expected signal-strength differentials is to “ensure that ‘apples are compared with apples’” in the comparison of expected signal-strength values and reported signal-strength values in estimating the location of a wireless terminal. *Id.* Based on these disclosures, in at least some circumstances, expected signal-strength differentials are generated for comparison against signal-strength differentials computed from Signal 1 (“R(1,n)”) and Signal 2 (“R(2,n)”) such that generation of the expected signal-strength differentials “*uses a difference between said first and second signal characteristics.*”

12. *Claim 21*

[21] The method of claim 14 wherein said first signal characteristic is signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.

153. Bhattacharya-Spain renders [21] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.10.

154. For example, as noted in Section XI.B.8 and X.A.6, base station 202-2 represents an example of a “*serving transmitter*” in the network of geographic

region 200 since “wireless terminal 201 is serviced by base station 202-2.”

APPLE-1005, [0003], [0055]. Further, signal-strength measurement, R(2,n) (or Signal 2) is associated with base station 202-2 and thereby the “***first signal characteristic.***” APPLE-1005, [0086]. Further, since “Signal 2 is the overhead control channel broadcast by base station 202-2,” R(2,n) (or Signal 2) is the “***signal strength of a control channel transmitted by said serving transmitter and received by said mobile station.***” *Id.*

13. *Claim 22*

[22] The method of claim 21 wherein said collecting observed network measurement data further includes collecting a second signal characteristic from a neighboring transmitter wherein said second signal characteristic is signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.

155. Bhattacharya-Spain renders [22] obvious for the same reasons discussed above in Ground 1A. *See* Section X.A.11.

156. For example, as noted in Section XI.B.8 and X.A.6, base station 202-2 is an example of a serving transmitter, and thus, base stations 202-1 and 202-3 are examples of a “***neighboring transmitter.***” APPLE-1005, [0003], [0055]. Further, signal-strength measurement, R(1,n) (or Signal 1) is associated with a base station 202-1 and thereby the “***second signal characteristic.***” APPLE-1005, [0086].

Further, since “Signal 1 is the control channel broadcast by base station 202-1,”

R(1,n) (or Signal 1) is the collected “*signal strength of a control channel transmitted by said neighboring transmitter and received by said mobile station.*”

Id.

14. *Other Claims - Claims 4, 15, and 16*

157. Bhattacharya-Spain renders these claims obvious in the same manner as explained above for the corresponding claims listed in the table below.

Claim	Corresponding Claim	Corresponding Evidence
[4], [15]	[3]	APPLE-1001, 3:57-67; APPLE-1005, [0085]-[0090], [0115]; APPLE-1006, [0006], [0070], [0076]-[0082], [0098], [0099], FIGS. 6A, 6E
[16]	[12]	APPLE-1005, [0051], [0055], [0057], [0058], [0063], FIG. 2; APPLE-1006, [0076], [0086], [0102], [0202]

XII. [GROUND 1C] – BHATTACHARYA AND MEUNIER MAKES CLAIMS 25, 27, 29, 31, 32, AND 35 OBVIOUS

A. Combination of Bhattacharya and Meunier

158. As discussed above, Bhattacharya and Meunier each focus on systems that detect a location of a mobile device (e.g., Bhattacharya’s wireless terminal 201, Meunier’s mobile device 100) in a certain region. APPLE-1005, Abstract; APPLE-1007, Abstract. In each reference, a location of the mobile device is

determined based on signal strength measurements of wireless communications with nearby base stations (e.g., Bhattacharya's base stations 202-1, 202-2, 202-3, Meunier's base stations). APPLE-1005, FIG. 2; APPLE-1007, [0012], [0016].

While Bhattacharya indicates "signal-strength measurement errors" may be made by wireless terminal 201, its contemplated techniques to correct (or compensate for) such errors is primarily through device-specific calibration. APPLE-1005, [0097].

159. Bhattacharya's calibration function "enables location system 212 to calibrate [] reported signal-strength measurements from wireless terminal 201 based on the make and model of the wireless terminal." APPLE-1005, [0088]. This is accomplished using a "distortion function" based on "make and model" of the terminal 201. *Id.*, [0136]. Yet, a POSITA would have recognized that Bhattacharya's distortion function does not address other types or measurement errors that are not necessarily tied to make and model of the terminal 201, such as measurement errors relating to device movement during time points where signal-strength measurements are collected and reported. Bhattacharya is silent on how its location estimation technique may be impacted by the lack of measurement reliability in using signal strength measurements for location estimation. This would have led a POSITA looking to implement its teachings to search for reasonable solutions beyond its disclosure. *Id.*

160. In conducting this search, a POSITA would have discovered Meunier, which, further discloses techniques to improve aspects of location detection based on signal strength measurements of wireless communications. Although Meunier purports to address problems in WiFi networks, its solution is applicable more generally to various wireless networks, including wireless LANs that use base stations, as indicated by no mention of WiFi in its detailed description disclosure and claims. *See generally*, APPLE-1007. A POSITA would have perceived Meunier to be pertinent to improving the reliability of Bhattacharya's system, e.g., to take into account environmental factors (e.g., movement of people or large objects) and signal strength data that varies with device orientation. APPLE-1007, [0003], [0012]-[0014], [0019]-[0021]. And since Meunier addresses how device movement impacts location estimation accuracy and reliability, a POSITA would have understood and found obvious that similar impacts may also implicate the Bhattacharya system. APPLE-1007, [0006], [0016], [0019]-[0021].

161. A POSITA would have looked to incorporate Meunier's use of "statistical correction algorithms" in improving location detection performance, such as measuring signal strength values, applying statistical correction to the wireless signal strength values if the mobile device is moving less than a threshold amount, and using the resulting values in location estimation. APPLE-1007, [0006], [0007]. Meunier explains that "[v]arious statistical correction algorithms

may be used.” APPLE-1007, [0007]. One example of a statistical correction algorithm is to “use a moving window of N signal strength samples” to compute an “average value and standard deviation of the signal strength” for each base station.” APPLE-1007, [0007], [0016].

162. As discussed in Section IX.C, Meunier describes using average signal strength measurements to “improve accuracy of the location detection if the user is stationary [,]” (*id.*, [0016]), e.g., device movement is below a “cut off threshold” where “small movements” are ignored (*id.*, [0014]). Given Meunier’s teachings of using average signal strength values to improve accuracy in location determination in scenarios where movement is below a cut off threshold, a POSITA would have been motivated to incorporate Meunier’s techniques into Bhattacharya, which would have imparted similar advantages to Bhattacharya’s location estimation techniques in similar scenarios. APPLE-1007, [0016].

163. As discussed below, Bhattacharya-Meunier would have offered two new capabilities to a combined terminal (relative to Bhattacharya’s wireless terminal 201) that each would have improved Bhattacharya’s underlying location estimation technique by location system 212. First, the combined terminal would have leveraged conventional motion sensors (e.g., accelerometer) to monitor device movements and compare the monitored movements to a cut off threshold (as taught in Meunier). Second, the combined terminal would have computed

average signal strength values (modified through statistical correction algorithms) for each base station within a geographic region in scenarios when device movement is below the cut off threshold, and then provided the average signal strength values for use in computing signal-strength differentials. APPLE-1007, [0012].

(i) Device Movement

164. A POSITA would have configured the Bhattacharya-Meunier terminal to incorporate Meunier's technique of monitoring device movement, e.g., through the use of "a motion detector (such as an accelerometer) for detecting motion of the mobile device," while collecting signal-strength measurements from nearby base stations and comparing the monitored device movement to a predetermined threshold. This would have allowed the terminal to differentiate between the two scenarios addressed in Meunier. As discussed in Section XII.A, in the first scenario, where device movement is below the cut-off threshold, statistical correction algorithms are applied to subsequently compute average signal strength values for each base station and "improve[s] accuracy of the location detection." APPLE-1007, [0016]. In the second scenario, device movement is above the cut off threshold and location estimation should "fall back on guessing location based

on solely on the instantaneous signal strength,” consistent with techniques already described in Bhattacharya. *Id.*, [0017]; *see* APPLE-1005, [0091]. A POSITA would have understood and found obvious that either scenario involves using similar signal strength information for a set of base stations and would not have necessitated additional functionality in Bhattacharya’s location system to differentiate between the two scenarios.

(ii) Average Signal Strength

165. As discussed above, a POSITA would have also implemented Bhattacharya-Meunier such that a combined wireless terminal monitors signal strength measurements from nearby base stations, and in certain scenarios, performs statistical correction (e.g., by computing average signal-strength values for the nearby base stations), and then use the computed average signal-strength values to subsequently perform location estimation. APPLE-1005, [0091]-[0094]; APPLE-1007, [0012], [0015], [0006]-[0008].

166. Meunier discloses embodiments involving “[t]he use of a wireless local-area network to detect the location of a device within the area covered by the network.” APPLE-1007, [0002]. Yet a POSITA would have understood that Meunier’s teachings are not limited to these embodiments given a broader articulation of its invention as relating to “a method for determining the proximity of mobile devices in a wireless network.” Meunier’s Abstract similarly lacks

discussion of WLAN infrastructure, and instead, offers non-limiting disclosure that its location estimation techniques may involve “a wireless signal strength of *any* received network radio signals.” *Id.*, Abstract; [0006] (same). A POSITA would have understood and found obvious that Meunier may be readily combined with location detection systems using well-known wireless network radio signals, such as the Bhattacharya system. Further, the use multiple wireless communication standards in location estimation systems was well-known before the Critical Date. APPLE-1010, 22:63-23:2.

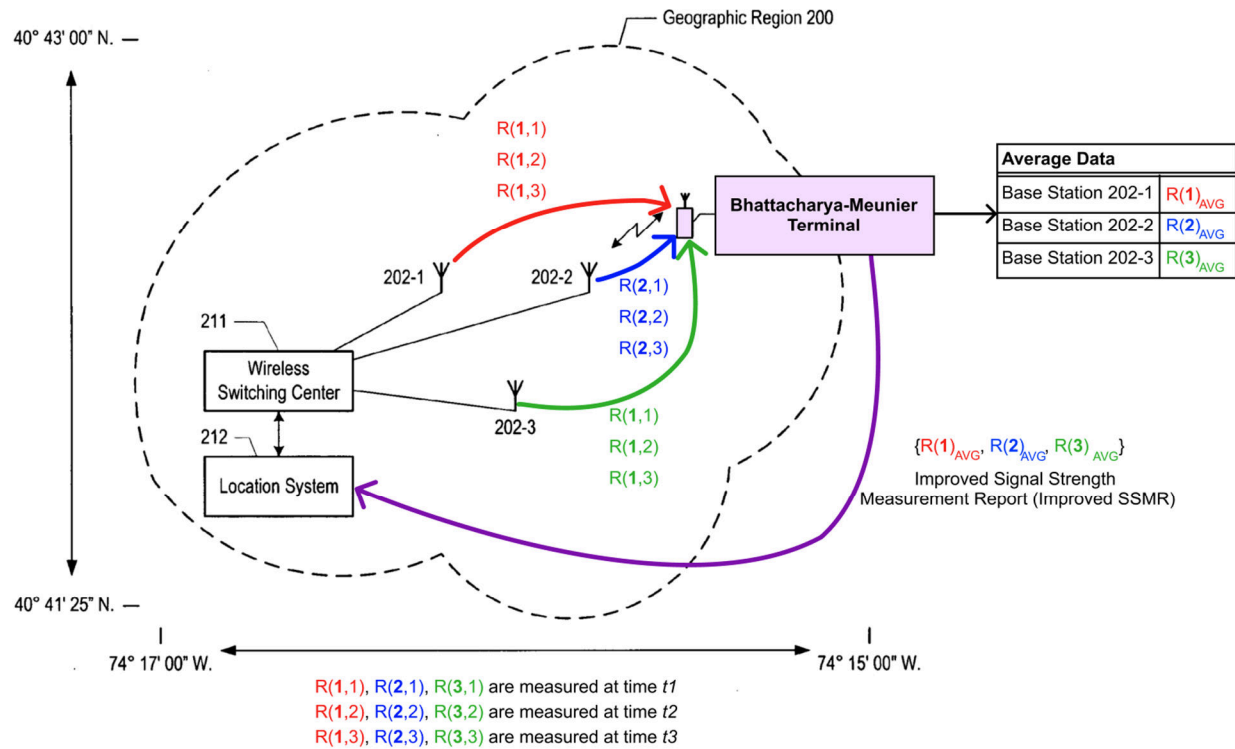
167. Specifically, a wireless terminal of Bhattacharya-Meunier would have leveraged Meunier’s technique to compute “the average value and standard deviation of the signal strength...for each base station” from these signal strength values for various base stations. APPLE-1007, [0016]. This would have enabled the terminal to provide the average values in a modified SSMR to a location system. *Id.*; APPLE-1005, [0091].

168. A POSITA would have understood and found obvious that, upon receiving the modified SSMR from the combined terminal, the location system of Bhattacharya-Meunier would have performed calibration and computed signal-strength differentials using the average values and the same mathematical techniques described in Bhattacharya. As discussed above, because average signal strength values represent the same signal strength information as that described in

Bhattacharya, use of average values (in place of instantaneously-measured values) in computing signal-strength differentials would not have meaningfully changed the functionality of the Bhattacharya's location system 212 in location estimation. APPLE-1007, [0014]. Such a configuration would have enjoyed the benefits associated with using averaging for statistical correction (per Meunier), while also maintaining the ability to compute signal-strength differentials for location estimation (per Bhattacharya).

169. Below is an example of a modified location estimation technique provided by Bhattacharya-Meunier using average values in scenarios where movement of the combined device is below a cut off threshold, as discussed above. I created this figure by annotating and modifying Bhattacharya's FIG. 2 based on the teachings of Meunier, as I have described in Sections XII.A and XII.B.

Figure 2



Bhattacharya -Meunier

170. Finally, a POSITA would have reasonably expected to succeed in incorporating Meunier into Bhattacharya because the combination would have required only routine knowledge well within the skill of a POSITA prior to the earliest effective filing date. Meunier states that “addition of small low cost motion detectors (such as accelerometers) and electric compasses to the mobile device should not appreciably increase the mobile device’s size, price or power consumption.” APPLE-1007, [0021]. APPLE-1005, [0140].

B. Analysis

1. *Claim 25*

171. Bhattacharya-Meunier renders several limitations of claim 25 obvious in the same manner as explained above in Ground 1A for the corresponding claim 1 limitations listed in the table below.

Claim 1 Limitation	Corresponding Limitations
[1.1]	[25.1]
[1.2]	[25.2]
[1.4]	[25.4]
[1.6]	[25.7]

172. Features uniquely recited in claim 25 are addressed below.

[25.3] collecting observed network measurement data from each of a plurality of transmitters including a signal characteristic from each one of said plural transmitters,

173. This limitation is nearly identical to [1.3], but requires “***observed network measurement data***” to (i) be collected from “***each of a plurality of transmitters,***” and (ii) include “***a signal characteristic from each one of said plural transmitters.***” The “signal characteristic” term recited in this limitation encompasses a signal-strength measurement value. This is consistent with claim 18 of the ’494 patent, which further limits “signal characteristic” to “signal strength.” APPLE-1001, cl. 18. Further, the ’494 patent specification describes examples of operations where two “signal characteristics” are compared for a determination of

“a greater magnitude,” indicating that each of the signal characteristics are numerical values. *See* APPLE-1001, 2:21-26; *see also id.*, 10:21-35 (describing adjustments to values represented by signal characteristics).

174. As explained in Section XII.A, Bhattacharya-Meunier provides a location estimation technique in which a wireless terminal measures signal-strength measurements. Signal strength values or statistically-corrected values (e.g., average signal strength values) of the signal-strength measurements are determined and provided in a modified SSMR for subsequent use in computing signal-strength differentials (in a similar manner as described in Bhattacharya). APPLE-1005, [0091]; APPLE-1007, [0007], [0016]. A POSITA would have understood that the computing, storing, and subsequent transmission of the average signal strength values (“*observed network measurement data*”) in a modified SSMR encompasses “*collecting observed network measurement data.*” Details for determining the average signal strength value for each station are provided in [25.5] below

175. In addition, because the Bhattacharya-Meunier terminal would have collected signal strength measurements (“*signal characteristic*”) from nearby base stations, e.g., base stations 202-1, 202-2, and 202-3 (“*plurality of transmitters*”), and the average signal strength values are collected for each station, Bhattacharya-Meunier renders obvious [25.3]. APPLE-1005, [0091]-[0094], [0158]-[0160];

APPLE-1007, [0012]. Each of the signal-strength measurements for each of base stations 202-1, 202-2, 202-3 corresponds to a “*signal characteristic from each one of said plural transmitters*”). APPLE-1005, [0091]-[0094], [0158]-[0160].

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

176. The term “*average value*” recited in in this limitation represents a value computed as an arithmetic mean of “*select ones*” of the “*said signal characteristics*” (which, through antecedent basis, refers to the “*signal characteristic from each one of said plural transmitters*” recited in [25.3]).

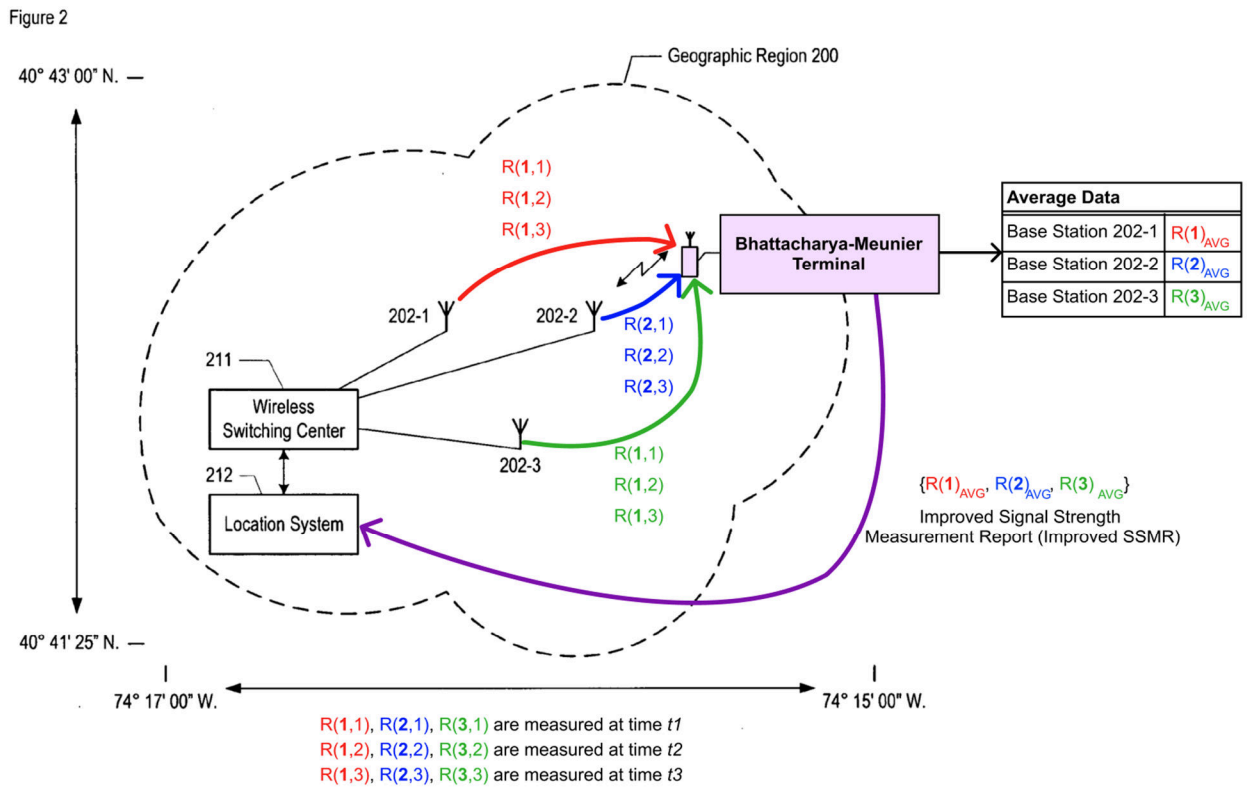
Without claim language indicating otherwise, the use of “*select ones*” in the claim leaves open the possibility of any selection of two or more signal characteristics amongst the signal characteristics. This includes, for example, (i) an average value determined for a selection of signal characteristics for a single base station, and (ii) an average value determined for a selection of signal characteristics across multiple base stations. As explained below, Bhattacharya-Meunier renders this limitation obvious through disclosures that satisfy the plain meaning of “average value” under example (i).

177. As discussed in Section XII.A, a POSITA would have configured Bhattacharya-Meunier to perform statistical correction of measured signal values by computing average values for signal-strength measurements for a particular base station in scenarios where device movement is below a cut off threshold.

APPLE-1007, [0016]. In such scenarios, the Bhattacharya-Meunier terminal would have provided a modified SSMR that includes average values for selected signal strengths measured for each base station (*“an average value for...said signal characteristic”*). APPLE-1005, [0091].

178. Further, average values determined by Bhattacharya-Meunier in these scenarios satisfy the plain meaning of “average value” (explained above). As discussed in [25.3], in one example of Bhattacharya-Meunier, the modified SSMR includes average signal strength values derived from signal-strength measurement for each of base stations 202-1, 202-2, 202-3. APPLE-1005, [0091]-[0094], [0158]-[0160]. In this example, each average value determined by Bhattacharya-Meunier is an arithmetic mean of multiple signal strength values measured for a single base station (e.g., base station 202-1). Because the average value is computed based on a selection of signal characteristics (i.e., measured signal strengths) that are specific to that single base station, the average value is determined for the selection of base station-specific signal characteristics (*“select ones”*) amongst signal characteristics for all base stations for which values are provided in the SSMR (*“said signal characteristics”*). For instance, if the mobile terminal measures/collects nine signal characteristics (three signal strength measurements for each of three base stations), then, in this instance, Bhattacharya-Meunier would have determined three average values (each of which is based on

the signal characteristics unique to each individual base station). Each average value would be determined for three of nine signal characteristics measured/collected by the mobile terminal, and thus, “*select ones*” of all signal characteristics. *Id.* An example of a modified or improved SSMR including the average signal strength values for each base station is shown in the figure below.



179. Additionally, for the mapping to Bhattacharya-Meunier, the plain meaning of “*select ones of said signal characteristics*” does not require a specific selection of a subset of signal characteristics for a particular base station. The claim language is broad enough to encompass selection of some or all of that

information. If this limitation is narrowly interpreted, a POSITA would have found it obvious to select, in the Bhattacharya-Meunier terminal, a subset of signal-strength measurements for a particular base station by leveraging Meunier's technique of "us[ing] a moving window of the last N signal strength samples" over a time window and then compute average values "[i]f at least M samples within the window are of sufficient quality (signal received from a minimum X number of wireless base stations)." *Id.*, [0016]. Such a configuration would have enjoyed the benefits of Meunier's teaching while maintaining the ability to compute signal-strength differentials for use in estimating a location of a mobile device (per Bhattacharya). *Id.*, [0012].

[25.6] modifying said observed network measurement data using said average value; and

180. As discussed in Section XII.A, [25.3], and [25.5] above, Bhattacharya-Meunier's terminal would have provided the average values in a modified SSMR to a location system. APPLE-1005, [0091]; APPLE-1007, [0016]. The modified SSMR includes three sets of an "average value" with each set corresponding to a particular base station.

181. After receiving a SSMR, the location system calibrates the reported signal strengths and calculates signal-strength differentials for reported and expected data in subtasks 1702 and 1703, respectively. *See supra* Section

X.A.1.[1.5]; APPLE-1005, [0179]-[0188]. In the Bhattacharya-Meunier process, the “*observed network measurement data*,” which includes the three average values for the three base stations, is modified through use of Bhattacharya’s distortion function and the average values of each of the base stations, with the distortion function adjusting the average values prior to subtracting the adjusted average values to compute the signal strength differentials. APPLE-1005, [0023]-[0026], [0057], [0081]-[0088], [0168]-[0170]. For instance, using serving cell 2 and base station 2 as the reference, the observed network measurement data would be calibrated and modified by the average signal strength value associated with the second base station using Bhattacharya’s Equation 7 such that the calibrated average signal strength values of the first and third base stations, respectively, would be subtracted, as shown below, from the calibrated average signal strength value of the second base station. APPLE-1005, [0182], [0097], [0127].

$$\Delta N(2,n) = [\{S_{avg}(2, n) - S_{avg}(1, n)\}, \{S_{avg}(2, n) - S_{avg}(3, n)\}]$$

182. A POSITA would have understood that, combining the teachings of Meunier with Bhattacharya in the above-noted matter, would have been consistent with Bhattacharya’s method. Instead of using measured signal strength values at a particular time, the Bhattacharya-Meunier system uses average signal strength values for purposes of location estimation.

2. *Claim 32*

[32] The method of claim 25, wherein the observed network measurement data includes received signal strength of said transmitters as said mobile station.

183. As explained for [25.3]-[25.6] and [1.4], Bhattacharya-Meunier's "**observed network measurement data**" includes average values of the signal strengths measured at a wireless terminal and thus includes "**received signal strength of said transmitters as said mobile station.**" APPLE-1005, [0091]-[0094], [0158]-[0160]; APPLE-1007, [0012], [0016].

3. *Claim 35*

[35] The method of claim 25 wherein at least one of said plurality of transmitters is not a member of said wireless network.

184. As discussed for [25.4], a POSITA would have configured the Bhattacharya-Meunier terminal to collect signal-strength measurements from nearby base stations, e.g., base stations 202-1, 202-2, and 202-3. APPLE-1005, [0091]-[0094]; APPLE-1007, [0012]. Bhattacharya describes some embodiments in which a wireless terminal provides "signal strength measurements that have nothing to do with providing telecommunications service to wireless terminal 201," where the additional signal strength measurements are provided "in addition to" the measurements from base stations 202-1, 202-2, and 202-3 (" $\{R(1,n), R(2,n), R(3,n)\}$ "). APPLE-1005, [0166]. In such embodiments, a base station that provides the additional signal strength data may not be associated with a

telecommunications network (“**wireless network**”) serviced by base stations 202-1, 202-2, and 202-3, and thus are “**not a member of said wireless network.**”

185. Bhattacharya-Meunier also renders this claim obvious through Meunier’s “use of wireless local-area network to detect the location of a device within [an] area covered by [a] network.” APPLE-1007, [0002]. In Meunier, “[w]ireless LANs can be used...for determining locations of mobile devices by analyzing the signal strengths from multiple fixed base stations.” *Id.*, [0006]. Thus, a POSITA would have understood and found obvious that implementations of the Bhattacharya-Meunier incorporate hardware and software to communicate with cellular base stations (e.g., Bhattacharya’s base stations 202-1, 202-2, 202-3) and WLAN base stations (e.g., Meunier’s base stations) and thereby is configured to collect signal strength measurements from each for location estimation. In such implementations, a WLAN base station is not associated with a telecommunications network (“**wireless network**”) serviced by base stations 202-1, 202-2, and 202-3, and thus, is “**not a member of said wireless network.**” *Id.*, APPLE-1007, [0005].

4. *Other Claims - Claims 27, 29, and 31*

186. Bhattacharya-Meunier renders these claims obvious in the same manner as explained above for the corresponding claim limitations listed in the table below.

Claim	Corresponding Claim(s)	Corresponding Evidence
[27]	[12]	APPLE-1005, [0055], [0057], [0058], [0063], FIG. 2
[29]	[18]	APPLE-1005, [0091]-[0094], [0158]-[0160]
[31]	[21]	APPLE-1005, [0003], [0055], [0086]

XIII. [GROUND 1D] – BHATTACHARYA, SPAIN, AND MEUNIER MAKES CLAIMS 25, 27, 29, 31, 32, AND 35 OBVIOUS

187. A POSITA would have found it obvious to combine Bhattacharya, Spain, Meunier for the reasons discussed in Section XI.A (Bhattacharya-Spain) and Section XII.A (Bhattacharya-Meunier). Further, because Bhattacharya-Spain-Meunier incorporates the features provided by Bhattacharya-Meunier, the combination renders the following claims obvious in the same manner as explained above for the corresponding claims listed in the table below:

Claim	Corresponding Evidence
[25]	APPLE-1005, [0091]-[0094]; APPLE-1007, [0012], [0016]
[27]	APPLE-1005, [0055], [0057], [0058], [0063], FIG. 2
[29]	APPLE-1005, [0091]-[0094], [0158]-[0160]
[31]	APPLE-1005, [0003], [0055], [0086]
[32]	APPLE-1005, [0003], [0055], [0086]

Claim	Corresponding Evidence
[35]	APPLE-1005, [0091]-[0094], [0166]; APPLE-1007, [0002], [0006], [0005], [[0012]

XIV. CONCLUSION

188. The findings and opinions set forth in this declaration are based on my work and examinations to date.

189. I may continue my examinations. I may also receive additional documentation and other factual evidence over the course of this IPR that will allow me to supplement and/or refine my opinions. I reserve the right to add to, alter, or delete my opinions and my declaration upon discovery of any additional information. I reserve the right to make such changes as may be deemed necessary.

190. In signing this declaration, I recognize that the declaration will be filed as evidence in an IPR before the PTAB. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

191. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the

knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

EXHIBIT A

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Education

- Georgia Institute of Technology, USA - Ph.D (ECE), 2006; M.S (ECE), 2003
- Anna University, India - B.S. (Electronics and Communications), 2001

Professional Experience

Professor School of ECE, Georgia Institute of Technology, Atlanta, USA	Oct 2021 – Present
Co-founder, CTO Wirinos Inc.	Jun 2023 – Present
Co-founder, CTO NavigatelO Inc.	Apr 2022 – Present
Senior Researcher NEC Labs America, Princeton NJ, USA	Aug 2006 – Sep 2021
Research Assistant Georgia Tech, Atlanta, USA	Aug 2001 – July 2006
Research Intern Intel Research, Cambridge, UK	Jan 2006 – Mar 2006
Research Intern Los Alamos National Lab, Los Alamos, USA	May 2005 – Aug 2005
Research Fellow AU-KBC Research Center, Chennai, India	May 2001 – Jul 2001

Awards/Honors

Professional/Academic

- IEEE Fellow, 2020 for contributions to algorithms for mobile networking and computing
- ACM Distinguished Member, 2018 for outstanding scientific contributions to computing.
- Association for Computing Machinery (ACM) SIGMOBILE Rockstar Award, 2016 – for early-career contributions to mobile connectivity ([Citation](#)).
- Business Contribution Award for LTE Small-cell Technology Commercialization, NEC 2015.
- University Gold Medal; ranking FIRST in academic performance, School of ECE, Anna University, Aug. 2001.
- Ramanujan Centennial Gold Medal for ranking FIRST in Mathematics courses across all disciplines during the four year under-graduate tenure, Anna University, Aug. 2001.
- Alumni Association's Best Outgoing Student Award, School of ECE, Anna University, Aug 2001.

Research

- Best Paper Award: “Is WiFi 802.11mc FTM Ready for Prime-time Deployment?”, ACM Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization, Oct 2022.
- Best Paper Award: “SkyCore: Moving Core to the Edge for Untethered and Reliable UAV-based LTE Networks”, ACM International Conference on Mobile Networking and Computing (MobiCom), Oct 2018.
- Best Paper Finalist: “BLU: Blue-printing Interference for Robust LTE Access in Unlicensed Spectrum”, ACM International Conference on Emerging Networking Experiments and Technologies (CoNEXT), Dec 2017.
- Best Paper Award: “MIDAS: Empowering 802.11ac Networks through Multiple-input Distributed Antenna Systems”, ACM International Conference on Emerging Networking Experiments and Technologies (CoNEXT), Dec 2014.
- Best Paper Award: “On Exploiting Diversity and Spatial Reuse in Relay-enabled Wireless Networks”, in ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc), May 2008.
- Best Paper Award: “Routing in Ad-Hoc Networks with MIMO Links”, in IEEE International Conference on Network Protocols (ICNP), Nov 2005.
- Best Paper Award: “Practical Limits on Achievable Energy Improvements and Useable Delay Tolerance in Correlation Aware Data Gathering in Wireless Sensor Networks”, in IEEE International Conference on Sensing, Communication and Networking (SECON), Sept. 2005.

Dissertations

- Sigma Xi Best Doctoral Thesis Award, Georgia Institute of Technology, USA, Apr. 2007. Thesis title: “Network Protocols for Ad-hoc Networks with Smart Antennas”
- Sigma Xi Best Master’s Thesis Award, Georgia Institute of Technology, USA, Apr. 2004. Thesis title: “MAC Protocols for Ad-hoc Networks with Switched Beam Antennas”
- Alumni Association’s Best Undergraduate Thesis Award, Anna University, INDIA, Aug. 2001. Thesis title: “Energy Allocation and Multiple Access for Multi-carrier Communication”

Commercialization/ Start-up

My work has also focused on translating research to high impact commercialization, technology transfer and start-up activities.

- Wirinos Inc.: Ultra-low power sustainable wireless tags for identification and high accuracy tracking in large scale supply chain and IoT applications
Led its innovative design and productization through GT’s Create-X start-up incubator program in 2023. Engaged in proof-of-concept trials for tracking personnel and medical devices/assets with healthcare providers; co-founder and chief technical officer of Wirinos Inc.
- NavigatelO Inc.: Infrastructure-free Tracking of First Responders in Dynamic GPS-denied Indoor Environments
Led its productization through NECx and Alchemist start-up accelerator programs. Successfully raised seed funding; ran numerous proof-of-concept trials with first responders since 2019; co-founder and chief technical advisor of NavigatelO Inc.

-
- FERMI: Self-Organizing Network Solution for Interference Management in Heterogeneous LTE Networks
Technology-transferred to NEC business units for commercialization through LTE small cell base stations, 2015. Received business award for commercialization.

Technical/Industry Experience

- Leading end-to-end R&D visions and groups targeting challenging problems in the wireless (networking, sensing, embedded and autonomous systems) space: identifying the key problems, coming up with technically (algorithmically) sound solutions, translating solutions to real-world systems
- Leading and mentoring a team of Ph.D researchers in accomplishing challenging R&D projects, as well as numerous Ph.D students and contributing to their thesis
- Translating research ideas to commercialization: deploying research prototypes in real-world, continuous iteration of solution (towards productization) based on user feedback
- Taking research solutions through start-up incubation and accelerator programs

Work Experience

Professor, School of ECE, Georgia Tech, Atlanta GA — Oct 2021 - Present

Director, MARGA (Mobile Advanced Research Lab at Georgia Tech) Lab

Leading a highly motivated group of graduate students on cutting-edge problems in mobile and wireless networks, sensing and computing.

PI on grant proposals (awarded):

- “ARMIN: Autonomous, Resilient Mobility Inverted Networks”, OUSD, Co-PI.
- “Adaptive 5G Core Network”, Strategic Initiative Proposal, Georgia Tech Research Institute (GTRI), Co-PI.
- “Seamless Coexistence of Positioning and Communications in 5G and Beyond Wireless Systems”, Sole PI, NSF.

Co-founder and Chief Technology Officer, Wirinos Inc. — 2023 - Present

Co-Inventor of an ultra-low power, high-accuracy wireless tracking solution for large scale supply chain and IoT applications. Developed the research solution with post-doc at MARGA, GT and incubated through GT’s Create-X accelerator program; co-founded the start-up in 2023. Engaged in successful PoCs with healthcare facilities.

Co-founder and Chief Technology Officer, NavigatelO Inc. — 2022 - Present

Inventor of an infrastructure-free, real-time, wireless tracking solution for challenging, GPS-denied indoor environments. Led the research solution from NEC labs through start-up incubation and co-founded the start-up. Numerous successful PoCs with first responder departments across the country, and federal grant recipient for the same.

Senior Researcher, NEC Labs America, Princeton NJ — 2006 - 2021

Led several challenging research projects in the Mobile Communications and Networking department. Recent research thrusts have been along three directions: (1) Confluence of 5G Networks and Autonomous Systems — exploring an alternate, paradigm of rapidly-deployable, on-demand, self-configurable mobile networks that can be hosted and driven by future, pervasive autonomous platforms (UAVs and AGVs). (2) Ultra Low Power Sensing — aims to remove several of the critical barriers in enabling

future on-body healthcare applications, by leveraging wireless backscattering to design novel, ultra low power (micro-W) wireless tags with significantly enhanced deployment, communication and sensing capabilities. (3) Tracking in Resource-constrained Environments — rethinking wireless localization and tracking solutions for practical applications like first responder (zero infrastructure support) situations, or massive scale (low-cost, low-power beacons) inventory tracking in warehouses that inherently operate in resource-constrained regimes.

Prior to these, earlier research thrusts have targeted: (i) wireless connectivity: pushed the performance envelope across multiple dimensions (capacity, latency, density, heterogeneity, user experience, availability) through novel network-level as well cross-layer (PHY+MAC) solutions. (ii) software-defined mobile computing: bringing software-defined computing and mobile connectivity together to enable demanding future applications ranging from massive scale Internet of Things (IoT) to high-bandwidth, low-latency Continuous Mobile Vision (eg. augmented/virtual reality), over mobile networks.

In addition to numerous publications and patents, work has received recognition through numerous awards both from company (for commercialization, startup incubation), as well as the broader research community (IEEE Fellow, ACM distinguished member, ACM early career award, and numerous best paper awards).

More information available at: <https://sites.google.com/view/karthik-s/home/research-latest>; some demos at: <https://sites.google.com/view/karthik-s/home/research/demos>.

Research Assistant, Georgia Tech, Atlanta GA — 2001 - 2006

Graduate research in the [GNAN](#) research group: focused on designing efficient network protocols for wireless networks that leveraged various forms of smart antennas. While advanced antenna technologies like MIMO were becoming popular at the physical layer (on isolated links), it was unclear how they can be effectively leveraged at higher layers of the protocol stack to deliver value to the network as a whole and to end applications. My thesis pushed the boundaries in this direction, and made significant advances in the design of algorithmically-sound solutions for leveraging such smart antennas in the network. My masters and doctoral theses received the best thesis awards at GaTech.

Research Intern, Intel Research, Cambridge UK, Jan – Mar 2006

Designed and implemented algorithms for self-organizing wireless LANs. The algorithms leveraged several cross layer parameters such as load, average contention duration, etc. that were measured at the firmware and instrumented for access at the driver. The algorithms were implemented in the device driver and tested in Intel's wireless LAN access points & client devices. This work was published in ACM IMC 2006.

Research Intern, Los Alamos National Lab, Los Alamos NM, May - Aug 2005

Investigated the problem of communication in multi-hop wireless networks with smart antennas from a combinatorial perspective in the discrete simulation science division. This involved the design of efficient centralized as well as purely localized algorithms with performance guarantees to help nodes determine the optimal usage of available degrees of freedom to improve network utilization; and resulted in a publication in ACM MobiHoc 2006. I also designed and implemented MAC protocols for wireline networks as part of a highly scalable network simulator.

Research Fellow, AU-KBC Research Center, Chennai India, May - Aug 2001

Designed a novel, adaptive allocation algorithm for multi-user OFDM communication systems that minimizes the total transmit power by optimally allocating OFDM sub-carriers and data bits based on instantaneous channel information. This work was later published in Wireless Personal Communications Journal, (Kluwer) Apr 2003.

Research Contributions

- 60+ awarded patents (Appendix A)
- 100+ research papers in top-tier IEEE and ACM conferences and journals, and book chapter (Appendix B)
- Several invited talks, tutorials, seminars, keynotes and panels (Appendix C)

Professional Activities

- Several leadership (technical and organizational) roles in top tier conferences; service on numerous international-level research review panels, committees and editorial boards (Appendix D)

Patents (Appendix A)

Expert Reviewer

- Broadcom vs. Netflix, retained by Adsero IP LLC, 2022; US Patent # 7,103,794
- Broadcom vs. Netflix, retained by Adsero IP LLC, 2022; US Patent # 8,646,014
- Daingean vs. AT&T, retained by Heim, Payne & Chorush, L.L.P., 6 patents
- Apple Inc. vs. Geoscope Tech., retained by Fish & Richardson P.C., 3 patents

Awarded

1. Infrastructure-free RF Tracking in Dynamic Indoor Environments, US patent # 11,388,564, Jul 2022.
2. Un-manned Aerial Vehicle Network, US patent # 11,356,172, Jun 2022.
3. Tracking Indoor Objects with Inertial Sensor Measurements, US patent # 11,169,518, Nov 2021.
4. Tracking Indoor Objects from an Unmanned Aerial Vehicle, US patent # 11,089,432, Aug 2021.
5. Self-configuring Long Term Evolution Radio Access Network on Unmanned Autonomous Vehicles, US patent # 11,054,843, Jul 2021.
6. Backscatter-aided Navigation System, US patent # 10,852,415, Dec 2020.
7. In-home Inventory and Location System, US patent # 10,852,414, Dec 2020.
8. Tagging Objects in Indoor Spaces using Ambient, Distributed Backscatter, US patent # 10,852,413, Dec 2020.
9. In-store Interaction and Location System for Interfacing Users with Products, US patent # 10,852,416, Dec 2020.
10. Signaling for Coordinated Multi-point Transmission and Reception, US patent # 10,616,880, Apr 2020.
11. Speculative Scheduling in Wireless Networks, US patent # 10,582,529, Mar 2020.
12. Interference Topology Inference to Enhance Performance of LTE Unlicensed Networks, US patent # 10,574,535, Feb 2020.
13. Implementing Wireless Communication Networks using Unmanned Aerial Vehicles, US patent # 10,470,243, Nov 2019.
14. System and Method for Enabling Interference Awareness for LTE Operation in Unlicensed Spectrum, US patent # 10,469,188, Nov 2019.
15. Product Checkout and Interest Detection in Retail Environment using Radio Frequency Identification, US patent # 10,410,025, Sept 2019.

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16. Distributed Architecture for Implementing Wireless Communication Networks, US patent # 10,405,373, Sept 2019.
 17. Blue-printing Interference for LTE Access In Unlicensed Spectrum, US patent # 10,405,209, Sept 2019.
 18. Battery-free Touch-aware User Input using RFID Tags, US patent # 10,346,655, July 2019.
 19. Systems and Methods for Distributed Assignment of Task Identifiers, US patent # 10,331,493, June 2019.
 20. Design of Randomization Function and its Application in Load Balancing, US patent # 10,298,671, May 2019.
 21. Consistent Hashing, US patent # 10,296,394, May 2019.
 22. Enabling Technologies for LTE on Unlicensed Spectrum, US patent # 10,292,054, May 2019.
 23. Enabling High-bandwidth Responsive Mobile Applications in LTE Networks, US patent # 10,122,547, Nov 2018.
 24. Interference Alignment in a Network with Asymmetrical Channel Dimensions, US patent # 10,110,293, Oct 2018.
 25. Asynchronous Access and Synchronous Transmission for Coexistence of Wireless Standards, US patent # 10,091,114, Oct 2018.
 26. Software-driven Long-Term Evolution Core Network for Mobile Access, US patent # 10,021,172, July 2018
 27. Efficient Network-wide Broadcasting over LTE Networks, US patent # 9,967,860, May 2018.
 28. Enabling Long Term Evolution/WiFi Coexistence, US patent # 9,936,414, Apr 2018.
 29. System and method for dynamic provisioning of Wi-Fi capacity in large venues using a C-RAN architecture, US patent # 9,813,944, Nov 2017.
 30. Scaling Wireless Full-Duplex in Multi-Cell Networks, US patent # 9,722,720, Aug 2017.
 31. Intelligent WiFi-offloading for Next-generation Mobile Networks, US patent # 9,723,532, Aug 2017.
 32. Degrees of Freedom in Multi-cell Wireless Systems with Full-duplex Base Stations using Interference Alignment, US patent # 9,736,785, Aug 2017.
 33. Method and Apparatus for Powerline Communication and Networking in Multi-flow Environments, US patent # 9,654,174, May 2017.
 34. Efficient Large Scale Multiple Input Multiple Output Communications, US patent # 9,413,474, Sept 2016.
 35. Multi-user Multiple Input Multiple Output (MIMO) Communication with Distributed Antenna Systems in Wireless Networks, US patent # 9,450,654, Sept 2016.
 36. Carrier Aggregation, US patent # 9,337,966, May 2016.
 37. Multiple-Input Multiple-Output Wireless Communications With Full-Duplex Radios, US patent # 9,137,788, Sept 2015.
 38. A Cloud Based Radio Access Network for Small Cells, US patent # 9,125,047, Sept 2015.
 39. Tailoring Wireless Transmission Strategies to User Profiles in Cloud Based Radio Access Networks, US patent # 9,066,351, Jun 2015.
 40. Methods and Apparatus for Integrating Batch Scheduling with External Beamforming, US patent # 8,976,696, Mar 2015.
 41. Scalable Network MIMO for Wireless Networks, US patent # 8,923,907, Dec 2014.
 42. Coordinated Multi-Point Transmission, US patent # 8,891,604, Nov 2014.
 43. Method for a Canceling Self Interference Signal Using Active Noise Cancellation for Full- Duplex Simultaneous (in time) and overlapping (in space) Wireless
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- Transmission and Reception on the Same Frequency Band, US patent # 8,879,433, Nov 2014.
44. Method for a Canceling Self Interference Signal Using Passive Noise Cancellation for Full- Duplex Simultaneous (in time) and overlapping (in space) Wireless Transmission and Reception on the Same Frequency Band, US patent # 8,837,332, Sep 2014.
 45. Femtocell Resource Management for Interference Mitigation, US patent # 8,767,580, July 2014.
 46. Methods and Systems for Allocation of Macro Cell Resources in a Distributed Femtocell Network and a Distributed Relay Station Network, US patent # 8,780,849, July 2014.
 47. High Performance and Low Complexity Scheduling Method for Resource Usage in OFDMA Wireless Relay Networks, US patent # 8,660,030, Feb 2014.
 48. Channel Estimation Methods and Systems Based on Power Measurement at Receivers, US patent # 8,537,928, Sep 2013.
 49. Video Multicast Scheduling, US patent # 8,537,738, Sep 2013.
 50. Multicast Scheduling Systems and Methods for Leveraging Cooperation Gains in Relay Networks, US patent # 8,537,693, Sep 2013.
 51. Link Layer Multicasting Systems and Methods, US patent # 8,520,764, Aug 2013.
 52. Wireless Multicasting with Beamforming Antennas, US patent # 8,519,888, Aug 2013.
 53. Beamforming methods and systems employing measured power at a receiver to perform channel estimation, US patent # 8,380,133, Feb 2013.
 54. Methods and systems for location-based allocation of macro cell resources, US patent # 8,374,135, Feb 2013.
 55. Systems and methods for adaptive beamforming in indoor wireless networks, US patent # 8,340,584, Dec 2012.
 56. Methods and systems for allocation of macro cell resources in a distributed femto cell network and a distributed relay station network, US patent # 8,311,005, Nov 2012.
 57. Optimal beam scheduling for multicasting in wireless networks, US patent # 8,310,975, Nov 2012.
 58. Systems and methods for leveraging spatial reuse in OFDMA relay networks, US patent # 8,218,472, Jul 2012.
 59. High performance scheduling methods and apparatus for leveraging diversity in relay- enabled wireless networks, US patent # 8,170,031, May 2012.
 60. System and Method for Scheduling in Relay-assisted Wireless Networks, US patent # 8,134,946, Mar 2012.
 61. Integrated scheduling of unicast and multicast traffic in relay-enabled wireless networks, US patent # 8,098,609, Dec 2012.
 62. Method for scheduling heterogeneous traffic in B3G/4G cellular networks with multiple channels, US patent # 7,856,004, Jan 2010.

Publications (Appendix B)

Conference

1. M. Dasari, R. Sephardi, K. Sundaresan, S. Das, “RoVaR: Robust Multi-agent Tracking through Dual-layer Diversity in Visual and RF Sensing”, Proceedings of ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies (IMWUT), 2023.

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2. M. Rostami, K. Sundaresan, “Enabling High Accuracy Pervasive Tracking with Ultra Low Power UWB Tracking Tags”, Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2022.
 3. S. Aggarwal, R. Seshadri, K. Sundaresan, D. Koutsonikolas, “Is WiFi 802.11mc FTM Ready for Prime-time Deployment”, Proceedings of ACM Workshop on Wireless Network Testbeds, Experimental Evaluation and Characterization, **Best Paper Award**, Oct 2022.
 4. T. Woodford, X. Zhang, E. Chai and K. Sundaresan, “FishEye: Leveraging Diverse Reflector Geometries for Omni-directional Around-corner Automotive Radar”, Proceedings of ACM International Conference on Mobile Systems, Applications and Services (MOBISYS), June 2022.
 5. M. Rostami, X. Chen, Y. Feng, K. Sundaresan, D. Ganesan, “MIXIQ: Re-thinking Ultra Low Power Receiver Design for Next-generation On-body Applications”, Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2021.
 6. R. Seshadri, E. Chai, K. Sundaresan, S. Rangarajan, “SkyHaul” A Self-Organizing Gigabit Network in the Sky”, Proceedings of ACM International Symposium on Theory, Algorithmic Foundations and Protocol Design for Mobile Networks and Mobile Computing (MOBIHOC), July 2021.
 7. T. Woodford, X. Zhang, E. Chai and K. Sundaresan, “SpaceBeam: Lidar-driven One-Shot mmWave Beam Management”, Proceedings of ACM International Conference on Mobile Systems, Applications and Services (MOBISYS), June 2021.
 8. H. Alhulayyil, K. Apicharttrisor, J. Chen, K. Sundaresan, S. Oymak and S. Krishnamurthy, “WOLT: Auto-configuration of Integrated Enterprise PLC-WiFi Networks”, Proceedings of IEEE International Conference on Distributed Computing Systems (ICDCS), Nov 2020.
 9. M. Rostami, K. Sundaresan, E. Chai, S. Rangarajan, and D. Ganesan, “Redefining Passive in Backscattering with Commodity Devices”, Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2020.
 10. A. Dhekne, A. Chakraborty, K. Sundaresan, S. Rangarajan, “TrackIO: Tracking First Responders Inside Out”, USENIX Symposium on Networked Systems Design and Implementation (NSDI), Feb 2019.
 11. A. Chakraborty, E. Chai, K. Sundaresan, A. Khojastepour, S. Rangarajan, “SkyRAN: A Self-Organizing LTE RAN in the Sky”, ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2018.
 12. M. Moradi, K. Sundaresan, E. Chai, S. Rangarajan, “SkyCore: Moving Core to the Edge for Un-tethered and Reliable UAV-based LTE Networks”, Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), **Best Paper Award**, Oct 2018.
 13. R. Sheshadri, K. Sundaresan, E. Chai, S. Rangarajan, “ELI: Empowering LTE with Interference Awareness in Unlicensed Spectrum”, IEEE International Conference on Network Protocols (ICNP), July 2018.
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14. R. Sheshadri, K. Sundaresan, E. Chai, S. Rangarajan and D. Koutsonikolas, "BLU: Blue- printing Interference for Robust LTE Access in Unlicensed Spectrum", ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), **Best Paper Finalist**, Dec 2017.
 15. S. Pradhan, E. Chai, K. Sundaresan, S. Rangarajan, L. Qiu, "RIO: A Pervasive RFID-based Touch Gesture Interface", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2017.
 16. R. Sivaraj, M. Arslan, K. Sundaresan, S. Rangarajan, P. Mohapatra, "BoLTE: Efficient Network-wide LTE Broadcasting", Proceedings of IEEE International Conference on Network Protocols (ICNP), Oct 2017.
 17. A. Banerjee, R. Mahindra, K. Sundaresan, S. Rangarajan, S. Kasera, K. V-D. Merwe, "Orchestrating the Data Plane of Virtual LTE Core Networks", Proceedings of IEEE International Conference on Sensing, Communication and Networking (SECON), June 2017.
 18. S. Pradhan, E. Chai, K. Sunadresan, S. Rangarajan, L. Qiu, "Konark: A RFID-based System for Enhancing In-Store Shopping Experience", Workshop on Physical Analytics, Co-located with ACM MobiSys, June 2017.
 19. K. Apichattisorn, A. Fatya, J. Chen, K. Sundaresan, S. Krishnamurthy, "Enhancing WiFi Throughput with PLC Extenders", Passive and Active Measurements Conference (PAM), Mar 2017.
 20. J. Cho, K. Sundaresan, R. Mahindra, S. Rangarajan, J. V-d. Merwe, "ACACIA: Context-aware Edge Computing over Mobile Networks", ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2016.
 21. R. Seshadri, M. Arslan, K. Sundaresan, S. Rangarajan, D. Koutsonikolas, "AmorFi: Amorphous WiFi Networks for High Density Deployments", ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2016.
 22. E. Chai, K. Sundaresan, M. Khojastepour, S. Rangarajan, "LTE in Un-licensed Spectrum: Are We There Yet?", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2016.
 23. A. Atya, K. Sundaresan, S. Krishnamurthy, M. Khojastepour, S. Rangarajan, "BOLT: Enabling High-Throughput Powerline Communication Networks", ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2015.
 24. A. Banerjee, R. Mahindra, K. Sundaresan, S. Kasera, J. Van Der Merwe, S. Rangarajan, "SCALE: Scaling the LTE Control Plane for Future Wireless Access", ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2015.
 25. J. Xiong, K. Sundaresan, K. Jamieson, "ToneTrack: Leveraging Frequency-agile Radios for Time-based Indoor Wireless Localization", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Sept 2015.
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26. X. Xie, E. Chai, X. Zhang, K. Sundaresan, M. Khojastepour, S. Rangarajan, "Hekaton: Efficient and Practical Large-Scale MIMO", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Sept 2015.
 27. S. Singh, K. Sundaresan, S. Krishnamurthy, X. Zhang, M. Khojastepour, S. Rangarajan, "Trinity: A Practical Transmitter Cooperation Framework to Handle Heterogeneous User Profiles in Wireless Networks", Proceedings of ACM International Conference on Mobile Ad Hoc Networking and Computing (MOBIHOC), July 2015.
 28. M. Lotfi, K. Sundaresan, M. Khojastepour, S. Rangarajan, "The Economics of Quality-Sponsored Data in Wireless Networks", International Symposium on Modeling and Optimization in Mobile, Ad-hoc and Wireless Networks (WiOPT), May 2015.
 29. M. Khojastepour, K. Sundaresan, S. Rangarajan, "Scaling Wireless Full-duplex to Multi-cell Networks", IEEE International Conference on Computer Communications (INFOCOM), Apr 2015.
 30. J. Xiong, K. Sundaresan, K. Jamieson, M. Khojastepour, S. Rangarajan, "MIDAS: Empowering 802.11ac Networks with Multiple-input Distributed Antenna Systems", **Best Paper Award**, ACM International Conference on emerging Networking EXperiments and Technologies (CONEXT), Dec 2014.
 31. K. Sundaresan, M. Khojastepour, E. Chai, S. Rangarajan, "Full-duplex without Strings: Enabling Full-duplex with Half-duplex Clients", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Sept 2014.
 32. R. Mahindra, H. Viswanathan, K. Sundaresan, M. Arslan, S. Rangarajan, "A Practical Traffic Management System for Integrated LTE-WiFi Networks", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Sept 2014.
 33. J. Xiong, K. Jamieson, K. Sundaresan, "Synchronicity: Pushing the Envelope of Fine-grained Localization with Distributed MIMO", ACM Workshop on Hot Topics in Wireless, Sept 2014.
 34. M. A. Khojastepour, E. Aryafar, K. Sundaresan, S. Rangarajan, "Exploring the Potential of Full-Duplex in Legacy LTE Systems", Proceedings of IEEE International Conference on Sensing, Communication and Networking (SECON), June 2014.
 35. M. Khojastepour, K. Sundaresan, M. Farajzadeh-Tehrani, S. Rangarajan, "Degrees of Freedom per Communication Node", International Symposium on Modeling and Optimization in Mobile, Ad-hoc and Wireless Networks (WiOPT), May 2014.
 36. T. Bansal, K. Sundaresan, S. Rangarajan, P. Sinha, "R2D2: Embracing Device-Device Communication in Next Generation Cellular Networks", IEEE International Conference on Computer Communications (INFOCOM), Apr 2014.
 37. K. Sundaresan, M. Arslan, S. Singh, S. Rangarajan, S. Krishnamurthy, "FluidNet: A Flexible Cloud-based Radio Access Network for Small Cells", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Miami, Oct 2013.
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38. X. Zhang, K. Sundaresan, A. Khojastepour, S. Rangarajan, K. Shin, "NEMOx: Scalable Network MIMO for Wireless Networks", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Miami, Oct 2013.
 39. X. Xie, X. Zhang, K. Sundaresan, "Adaptive Feedback Compression for MIMO Networks", Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Miami, Oct 2013.
 40. K. Sundaresan, S. Rangarajan, "Energy-efficient Carrier Aggregation Algorithms for Next Generation Cellular Networks", Proceedings of IEEE International Conference on Network Protocols (ICNP), Oct 2013.
 41. A. Atya, A. Aqil, S. Singh, I. Broustis, K. Sundaresan, S. Krishnamurthy, "Mitigating Malicious Interference Via Subcarrier-level Radio Agility in Wireless Networks", Proceedings of IEEE International Conference on Network Protocols (ICNP), Oct 2013.
 42. J. Yoon, K. Sundaresan, A. Khojastepour, S. Rangarajan, S. Banerjee, "ProBeam: A Practical Multi-cell Beamforming System for OFDMA Small Cells", Proceedings of ACM International Conference on Mobile Ad Hoc Networking and Computing (MOBIHOC), Jul 2013.
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 44. M. Arslan, I. Singh, S. Singh, H. Madhyastha, K. Sundaresan, S. Krishnamurthy, "Computing while Charging: Building a Distributed Computing Infrastructure with Smartphones", ACM International Conference on emerging Networking Experiments and Technologies (CONEXT), Dec 2012.
 45. S. Singh, K. Sundaresan, A. Khojastepour, S. Rangarajan, S. Krishnamurthy, "One Strategy Does not Serve All: Tailoring Wireless Transmission Strategies to User Profiles", Proceedings of ACM Workshop on Hot Topics in Networks (Hotnets), Nov 2012.
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 47. M. Arslan, K. Sundaresan, S. Krishnamurthy, S. Rangarajan, "Design and Implementation of an Integrated Beamformer and Uplink Scheduler for OFDMA Femtocells", Proceedings of ACM International Conference on Mobile Ad Hoc Networking and Computing (MOBIHOC), Jun 2012.
 48. J. Yoon, M. Arslan, K. Sundaresan, S. Krishnamurthy, S. Banerjee, "A Distributed Resource Management Framework for Interference Mitigation in OFDMA Femtocell Networks", Proceedings of ACM International Conference on Mobile Ad Hoc Networking and Computing (MOBIHOC), Jun 2012.
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50. X. Zhang, M.A. Khojastepour, K. Sundaresan, S. Rangarajan, K. Shin, "Exploiting Interference Locality in Coordinated Multi-Point Transmission Systems", IEEE International Conference on Communications (ICC), June 2012.
 51. S. Barghi, M. Khojastepour, K. Sundaresan, S. Rangarajan, "Characterizing the Throughput Gain of Single Cell MIMO Wireless Systems with Full Duplex Radios", International Symposium of Modeling and Optimization of Mobile, Ad Hoc, and Wireless Networks (WIOPT), May 2012.
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 53. E. Aryafar, A. Khojastepour, K. Sundaresan, E. Knightly, S. Rangarajan, "ADAM: An Adaptive Beamforming System for Multicasting in Wireless LANs", in IEEE International Conference on Computer Communications (INFOCOM), Mar 2012.
 54. M. Arslan, J. Yoon, K. Sundaresan, S. Krishnamurthy, S. Banerjee, "Characterization of Interference in OFDMA Femtocell Networks", in IEEE International Conference on Computer Communications (INFOCOM) Mini-Conf, Mar 2012.
 55. A. Khojastepour, K. Sundaresan, S. Rangarajan, X. Zhang, S. Barghi, "The Case for Antenna Cancellation for Scalable Full Duplex Communications", Proceedings of ACM Workshop on Hot Topics in Networks (HotNets), Cambridge, Nov 2011.
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 60. S. Lakshmanan, K. Sundaresan, A. Khojastepour and S. Rangarajan, "Practical Multi-link Spatial Reuse in Wireless LANs", Proc. of IEEE International Conference on Broadband Communications, Networks, and Systems (BROADNETS), Athens, Greece, Oct 2010.
 61. K. Sundaresan and S. Rangarajan, "Cooperation vs. Multiplexing: Multicast Scheduling Algorithms for OFDMA Relay Networks", Proceedings of ACM International Conference on Mobile Ad Hoc Networking and Computing (MOBIHOC), Chicago, Sept 2010.
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 70. K. Sundaresan and S. Rangarajan, "On Coexistence of Unicast and Multicast Traffic in Relay- enabled Wireless Networks", Proceedings of IEEE International Conference on Broadband Communications, Networks, and Systems (BROADNETS), London, UK Sept 2008.
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 76. K. Sundaresan, and R. Sivakumar, "Cooperating with Smartness: Using Heterogeneous Smart Antennas in Ad-Hoc Networks", Proceedings of IEEE International Conference on Computer Communications (INFOCOM), Anchorage, Alaska, May 2007.
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 78. K. Sundaresan, S. Lakshmanan and R. Sivakumar, "On the Use of Smart Antennas in Multi- Hop Wireless Networks", Proceedings of International Conference on Broadband Communications, Networks, and Systems (BROADNETS), San Jose, USA, Oct 2006.
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Journals

82. M. Moradi, K. Sundaresan, E. Chai, S. Rangarajan, "SkyCore: Moving Core to the Edge for Un-tethered and Reliable UAV-based LTE Networks", Communications of the ACM, Research Highlights, Jan 2021.
 83. M. Moradi, K. Sundaresan, E. Chai, S. Rangarajan, "SkyCore: Moving Core to the Edge for Un-tethered and Reliable UAV-based LTE Networks", ACM Sigmobile, GetMobile Magazine, Research Highlights, 2019.
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 86. S. Singh, K. Sundaresan, S. Krishnamurthy, X. Zhang, M. Khojastepour, "Trinity: Tailoring Wireless Transmission Strategies to User Profiles in Enterprise Wireless Networks", in IEEE/ACM Transactions on Networking, 2017.
 87. J. Yoon, K. Sundaresan, M. Khojastepour, S. Rangarajan, S. Banerjee, "Joint Multi-cell Beamforming and Client Association in OFDMA Small-cell Networks", in IEEE Transactions on Mobile Computing, 2016.
 88. K. Sundaresan, M. Arslan, S. Singh, S. Rangarajan, S. Krishnamurthy, "FluidNet: A Flexible Cloud-based Radio Access Network for Small Cells", in IEEE/ACM Transactions on Networking, 2016.
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 93. S. Singh, M. Shahbazi, K. Pelechrinis, K. Sundaresan, S. Krishnamurthy, K. Satish, "Adaptive Sub-carrier Level Power Allocation in OFDMA Networks", IEEE Transactions on Mobile Computing, 2015.
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 95. K. Sundaresan, S. Rangarajan, "Video Multicasting with Channel Diversity in Wireless OFDMA Networks", in IEEE Transactions on Mobile Computing, 2014.
 96. K. Sundaresan, S. Rangarajan, "Cooperation vs. Multiplexing: Multicast Scheduling Algorithms for OFDMA Relay Networks", in IEEE/ACM Transactions on Networking, 2014.
 97. E. Aryafar, M. Khojastepour, K. Sundaresan, S. Rangarajan, M. Chiang, "ADAM: An Adaptive Beamforming System for Multicasting in Wireless LANs", in IEEE/ACM Transactions on Networking, 2013.
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 100. K. Sundaresan and R. Sivakumar, "Cooperating with Smartness: Using Heterogeneous Smart Antennas in Multi-hop Wireless Networks", in IEEE Transactions on Mobile Computing, Dec 2011.
 101. S. Lakshmanan, K. Sundaresan and R. Sivakumar, "Multi-gateway Association in Wireless Mesh Networks", in Ad-Hoc Networks Journal, Elsevier, May 2009.
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Mobile Computing Journal, Special Issue on Wireless Ad-hoc Networks: Technologies and Challenges, 2006.

- 105.K. Sundaresan, V. Anantharaman, H-Y. Hsieh and R. Sivakumar, "ATP: A Reliable Transport Protocol for Ad-hoc Networks", in IEEE Transactions on Mobile Computing, Nov-Dec 2005.
- 106.K. Sundaresan, R. Sivakumar, M. A. Ingram and T-Y. Chang, "Medium Access Control in Ad- hoc Networks with MIMO Links: Optimization Considerations and Algorithms", in IEEE Transactions on Mobile Computing, Oct-Nov 2004.
- 107.K. Sundaresan, H.-Y. Hsieh, and R. Sivakumar, "IEEE 802.11 over Multi-hop Wireless Networks: Problems and New Perspectives", in Ad-hoc Networks Journal, Elsevier, Feb 2004. WCMC
- 108.V. Anantharaman, S.-J. Park, K. Sundaresan, and R. Sivakumar, "TCP Performance over Mobile Ad-hoc Networks: A Quantitative Study", In Wireless Communications and Mobile Computing Journal (WCMC), Special Issue on Performance Evaluation of Wireless Networks, Mar 2004.
- 109.V. Rajendran, K. Sundaresan and S. Subramanian, "Performance of an OFDM Based Downlink Multiple Access System for Indoor Wireless Communications", in Wireless Personal Communications, Kluwer Academic Publishers, April 2003.

Book Chapters

- 110.K. Sundaresan, S-J. Park, and R. Sivakumar, "Transport Layer Solutions for Ad-hoc Networks", in Ad-hoc Networks: Technologies and Protocols, Kluwer, 2005.

Posters/Demos

- 111.J. Cho, K. Sundaresan, R. Mahindra, S. Rangarajan, J. V-d. Merwe, "ACACIA: Context-aware Edge Computing over Mobile Networks", Demo, Proceedings of ACM International Conference on Mobile Computing and Networking (MOBICOM), Oct 2016.
- 112.K. Sundaresan and R. Sivakumar, "Rate vs. Range vs. Reliability: How to Best Exploit MIMO in Ad-hoc Networks", Poster, Proceedings of ACM International Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC), Illinois, May 2005.
- 113.Y. Zhu, K. Sundaresan and R. Sivakumar, "Exposing Two Critical Myths About Correlation- Aware Data Aggregation", Poster, Proceedings of ACM International Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC), Illinois, May 2005.
- 114.K. Sundaresan and R. Sivakumar, "On the Medium Access Control Problem in Ad-hoc Networks with Smart Antennas", Poster, Proceedings of ACM International

Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC), MD USA, June 2003.

Tutorials

- “Networks in the Sky: Potential and Challenges”, at IEEE-sponsored COMSNETS, India, Jan 2022.
- “5G: An Evolution towards a Revolution”, at ACM MobiCom, India, Oct 2018.
- “5G: An Evolution towards a Revolution”, at Signal Processing and Communications Conference (SPCOM), IISC, Bengaluru, India, July 2018.

Talks (Appendix C)

Invited Panels, Tutorials and Talks

- “Architecting Networks in the Sky”, Keynote talk at ACM DroneNet workshop on Micro Aerial Vehicle Networks, Systems, and Applications, co-located with ACM Mobisys 2022.
- “Networks in the Sky: Enabling Ubiquitous Connectivity and Sensing”, Seminar talk at Georgia Tech, School of ECE, Feb 2021.
- “Untethering 5G for Ubiquitous Connectivity”, Invited talk at Comsnets, Jan 2021.
- “Making Mobile Networks Fly”, Seminar talk (Leaders and Innovators Series), at Texas A&M University, Nov 2019.
- “Making Mobile Networks Fly”, Keynote talk at ACM S3 workshop, co-located with ACM MobiCom, Oct 2018.
- “Triple Play: The Confluence of Connectivity, Computing and User Experience in Mobile Networks”, School of Computer Science, University of California, Santa Barbara, Apr 2017.
- “Connectivity meets Computing: A Wireless Networking Perspective”, School of Electrical Engineering, University of Washington, Seattle, Feb 2017.
- “Evolving Shades of Wireless Access Research”, ACM Sigmobile Rockstar Award talk, ACM MobiCom, Oct 2016.
- “Converged Wireless Access: The New Normal”, Talk at Wireless Co-existence Workshop, Univ. of Washington, June 2016.
- “Blurred Boundaries in Future Wireless Access”, Talk at 5G Forum, UCSD, May 2016.
- “Connectivity meets Computing: A Wireless Networking Perspective”, School of Computer Science, University of Utah, Apr 2016.
- “Blurred Boundaries in Future Wireless Access”, Talk at ACM Wireless Networking Industry Day, Mar 2016.

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- “Blurred Boundaries in Future Wireless Access”, Talk at ACM HotWireless Workshop, Sept 2015.
 - “Connectivity meets Computing in the Path to 5G”, Talk at Telecom ParisTech Workshop on 5G, Sept 2015.
 - “Connectivity meets Computing: A Wireless Networking Perspective”, School of ECE, UCSD, Feb 2015.
 - “Cloud-driven Architectures for Next Generation Small Cell Networks”, Keynote at ACM MobiArch workshop, co-located with ACM MobiCom, 2013.
 - “Cloud-driven Architectures for Next Generation Small Cell Networks”, Talk at University of Delaware, CS seminar, 2013.
 - “Realizing the Potential of Small Cells: An Experimental Approach”, Talk at Columbia University, EE seminar, 2012.
 - MIMO in Sensor and Ad Hoc Networks: Challenges and Opportunities” Panel at IEEE SECON 2008.

Professional Activities (Appendix D)

Editorial Board

Associate Editor, IEEE Transactions on Mobile Computing, Associate Editor, 2012-2018.

Conference/Workshop Organization

- Area Chair for IEEE ICNP, 2020.
 - Track Chair for IEEE ICDCS 2017, “Mobile and Wireless Network Computing” Track.
 - Program Co-Chair for ACM MobiCom 2016.
 - Program Co-Chair for IEEE ICC Workshop on “LTE in Unlicensed Bands: Potential and Challenges”, June 2015.
 - Program Co-chair for IEEE SECON 2013.
 - Poster Chair for ACM MobiHoc 2012.
 - Publicity Chair for ACM MobiCom 2010.
 - Publicity Chair for ACM MobiHoc 2010.
 - Poster and Demo Chair for IEEE SECON 2010.
 - Program Co-chair for IEEE Workshop on Wireless Mesh Networks (WiMesh) 2009; co- located with IEEE SECON 2009.
 - Publications Chair for ACM Workshop on Dependability Issues in Wireless Ad-hoc and Sensor Networks (DIWANS) 2006; co-located with ACM MOBICOM 2006.
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Award Committees

- ACM Sigmobile Test of Time Awards, 2023
- ACM Sigmobile Rockstar Award, 2017-2019

Technical Program Committee Memberships

- ACM MOBICOM 2008, 2011, 2012, 2014 - 2023.
- ACM SIGCOMM 2009.
- IEEE INFOCOM 2012, 2013, 2014, 2015 (advisory TPC), 2016, 2017.
- IEEE SECON 2009, 2012.
- IFIP Networking 2007, 2008.
- IEEE ICC 2010, 2012.
- IEEE MASS 2009.
- IEEE WoWMoM 2010.
- IEEE WiMesh 2009, 2010.

Referee/Panelist for Journals, Conferences and Review Panels

- Journals: IEEE/ACM Transactions on Networking, IEEE Transactions on Mobile Computing, IEEE Transactions on Wireless Communications, IEEE Journal on Selected Areas in Communications, ACM Mobile Computing and Communications Review
- Conferences: ACM MobiCom, ACM SIGCOMM, ACM CONEXT, IEEE INFOCOM, IEEE ICNP
- Evaluation committee of “MIMONet” project - a 3 year project on MIMO networks funded by Italian National Research Council, along with Dr. Robert Heath; Jan 2012.
- NSF Panelist for CISE, Network Technology and Systems 2012, 2013, 2014, 2017, 2019, 2023.

Ph.D. Dissertation Committees

- Mohammad Saad Zia, School of ECE, Georgia Tech, Atlanta, 2023.
- Shruti Lall, School of ECE, Georgia Tech, Atlanta, 2022.
- Yuchen Liu, School of ECE, Georgia Tech, Atlanta, 2022.

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- Mallesham Dasari, Computer Science, Stony Brook University, New York, 2021.
 - Mohammad Rostami, Computer Science, University of Massachusetts, Amherst, 2021.
 - Swadhin Pradhan, Computer Science, University of Texas, Austin, 2020.
 - Ashutosh Dhekne, School of ECE, UIUC, 2019