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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 1 of 2

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. _____

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
MARTIN	ALLES	16 Stonehaven Road, Hamilton Parish, FL04, Bermuda
JOHN	CARLSON	43479 Ogden Place, Dulles, Virginia 20166
GEORGE	MAHER	100 Adele Garden Way, Herndon ,Virginia 20170
SELCUK	MAZLUM	

Additional inventors are being named on the _____ *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max):

MOBILE LOCATION USING NETWORK MEASUREMENT REPORTS

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ The address corresponding to Customer Number:

OR

☒ Firm or Individual Name Duane Morris LLP

Address 1667 K Street, N.W., Suite 700

City	Washington	State	DC	Zip	20006
Country	US	Telephone	202.776.7800	Email	www.duanemorris.com

ENCLOSED APPLICATION PARTS *(check all that apply)*

☐ Application Data Sheet. See 37 CFR 1.76

☒ Specification *Number of Pages* 35

☐ Drawing(s) *Number of Sheets* _____

☐ CD(s), Number of CDs _____

☐ Other (specify) _____

Fees Due: Filing Fee of $200 ($100 for small entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

METHOD OF PAYMENT OF THE FILING FEE AND APPLICATION SIZE FEE FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27.

☒ A check or money order is enclosed to cover the filing fee and application size fee (if applicable).

☐ Payment by credit card. Form PTO-2038 is attached

☒ The Director is hereby authorized to charge the filing fee and application size fee (if applicable) or credit any overpayment to Deposit Account Number: 04-1679. A duplicative copy of this form is enclosed for fee processing.

$200.00

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[x] No.
[ ] Yes, the name of the U.S. Government agency and the Government contract number are: _____

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SIGNATURE _____ Date February 5, 2007

TYPED or PRINTED NAME Mark C. Comtois REGISTRATION NO. 46,285
(if appropriate)

TELEPHONE 202.776.7800 Docket Number: AND01 073

17712 U.S. PTO
020507

Attorney Docket No. AND01 073

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Sir:

Transmitted herewith for filing is the PROVISIONAL APPLICATION

for a patent of Inventor(s):

Martin Alles
16 Stonehaven Road
Hamilton Parish, FL04
Bermuda

John Carlson
43479 Ogden Place
Dulles, Virginia 20166

George Maher
100 Adele Garden Way
Herndon, Virginia 20170

Selcuk Mazlum

Title: MOBILE LOCATION USING NETWORK MEASUREMENT REPORTS

Enclosed are:

[X] A Cover Page and Three (35) pages of specification.

[X] A check in the amount of $200.00 to cover the filing fee.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 3 of 40

The Commissioner is hereby authorized to charge payment of any additional fees associated with this communication or to credit any overpayment to **Deposit Account No. 04-1679**. A duplicate of this sheet is enclosed.

Respectfully submitted,

Mark C. Comtois Reg. No. 46,285

DUANE MORRIS LLP
1667 K Street, N.W., Suite 700
Washington, DC 20006
Telephone: (202) 776-7800
Telecopier: (202) 776-7801

Dated: February 5, 2007

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 4 of 40

Intellectual Property Disclosure on Mobile Location using Network Measurement Reports

Date: 2/5/2007

Inventors: Martin Alles, John Carlson, George Maher, Selcuk Mazlum

The material contained in this report enumerates the various inventions developed within the signal processing group of Andrew Network Solutions based in Ashburn Virginia. These inventions are applicable to the problem of estimating the location of a mobile device when one or more Network Measurement Reports (NMRs) are generated by the network or the mobile in association with the unknown location of the mobile.

Acronyms: NUG – Non-Uniform Grid Point, UG – Uniform Grid Point, NMR- Network Measurement Report, NC – Neighbor Cell, pdf – probability density function, TA – Timing Advance, RTT – Round Trip Time, TDOA – Time Difference Of Arrival

Invention 1: A method for generating Non-Uniform Grid Points (NUGs) from calibration data

This method applies to the case where calibration data is available (obtained using one of many possible methods) over discrete points in a 2-dimensional region R (3-D is also possible as within large multi-level structures) R. This data, obtained at each discrete point (calibration point) could contain, but is not limited to, the following:

(a) Signal strengths observed for the signals transmitted by a set of transmitters of known location within or in proximity to the region R.
(b) Signal strength of a transmitter located at the calibration point as measured by a set of receivers of known location within or in proximity to the region R.
(c) Round trip time for a signal between the calibration point and an external known point.
(d) Time difference of arrival at the calibration point with respect pairs of external points located within or in proximity to R as measured by either a receiver at the calibration point or the external points.
(e) The serving cell or sector for a mobile wireless device operating at that calibration point.
(f) The network state at the time of collection – a finite number of such states may be required to distinguish between network conditions that vary diurnally, weekly or in some other manner.

For example, the case in (a) may apply to the IDEN specification, (c) may apply to the GSM specification as in the Timing Advance (TA) parameter or the Round Trip Time (RTT) parameter in the UMTS specification, (d) may apply to the UMTS specification, while the external receivers may be the base stations. In general, the data is any of those measurements made by a mobile wireless device located at the calibration point or any

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 5 of 40

measurement made on the transmissions or characteristics of the mobile wireless device at a set of external transmitter/receivers in the region R or in proximity to it.

The calibration data could consist of many such sets (vectors) obtained at each calibration point. At each calibration point, the data gathering could have resulted in either a single data vector or multiple data vectors, so that there are potentially multiple sets of data / data vectors associated with each calibration point.

A NUG generator could begin the NUG generation operation using

(a) a fixed uniform grid defined (UG) over the region R, with the calibration point data being assigned to the fixed grid points by some rule (e.g. allocated by closest fixed grid point)
(b) random grid points to define the start of each NUG
(c) combinations of (a) and (b) depending on the characteristics of the data

In any of these cases, the NUG generator evaluates the data vectors at a particular calibration point, or at the fixed grid point it is assigned. This calibration point or grid point serves as the root of the first NUG. The root of the NUG is the calibration data vector that initiates the creation of that NUG. The evaluation of the data vectors is of great importance since it is fundamental to the method. The vectors are examined using increasingly stringent tests of statistical sufficiency. In particular, we search for whether the data vectors exhibit clustering. If the data exhibits tight clustering, the data for the next candidate calibration point is aggregated to the former and the clustering property is re-evaluated. If the second also has a cluster but this cluster is sufficiently different, we deem that the data for the two considered calibration points should be allocated to the roots of separate NUGs. If the aggregate cluster is statistically very similar to either of the first clusters, the data for the two calibration points are allocated to the same NUG. All adjacent calibration data points are similarly evaluated with respect to the first considered calibration grid point. Thus the adjacent calibration points either wind up having all their data accumulated into a single NUG or at the other extreme, each such calibration point becomes the root of a separate NUG.

The primary test made to determine the allocation is one of a variety of clustering tests, such as for example the K-means algorithm, whereas the statistical similarity is determined by for example, the pdf of the data parameters (for example, NC signal levels, timing information etc.), the mean and variance of the data parameters, the serving cell/sector or other functions of the calibration data.

Those measurements or parameter values that do not cluster may be referred to as outliers. The performance of a grid-based pattern matching system is dependent on stored received signal level measurements that accurately reflect the levels that are likely to be reported by the mobile to be located. If the drive test data used to create the RF signal level grid contains outlier measurements, the statistically consistent value of the signal level will be distorted. This invention also describes the method used to identify and eliminate outlier signal level measurements and timing advance values (or in general, any

parameter within the NMR) during NUG or grid creation so as to improve the estimate of the mean parameter value.

In a very simple consideration of clustering, one could consider the mean value of a parameter. In this scenario, neighbor cell control channel signal level measurement outliers could be eliminated as follows: At each grid point, the average received signal level of a particular control channel signal is computed from all of the measurements of that signal assigned to the grid point. The deviation of each individual measurement from the mean is computed. Measurements that deviate by more than a configurable threshold from the mean are omitted. The average is recomputed without the omitted outliers. In a scenario where there are very few measurements, typically less than five or so, the original mean value will be greatly influenced by any outlier measurements and thus may falsely identify too many of the measurements as outliers, or fail to detect outliers. For this reason, another parameter is used to only perform the outlier check if there are at least a minimum number of measurements.

In the more general case, a cluster is a region in N-dimensional NMR vector space where there is a sufficient number of such vectors with a mutual variation that could be ascribed purely to noise in the measurement. Thus, if within a few feet of the original measurement if a particular parameter was blocked (say by a large structure such as a building) that would fall out of the original cluster. If sufficient such blocked locations have data falling near the original cluster, one would obtain a secondary cluster where the difference between the first and second clusters is the large variation in this particular parameter. It is useful to visualize such clustering in 2 or 3 dimensions to best grasp the concepts involved.

In addition, if any of the examined sets of data associated with a calibration point exhibit more then one cluster, it is necessary to define one or more co-located NUGs. Thus if there are three well defined clusters associated with a particular calibration point, these could form the roots of three co-located NUGs, the data in these NUGs growing depending on whether similar clusters can also be found in adjacent calibration points, in which case they are aggregated to the original NUGs or if not form separate root NUGs.

Further if the quantity of data associated with a particular calibration point is insufficient to sensibly test for statistical similarity or clustering, data for adjacent calibration grid points can be accumulated first and the statistical or clustering test performed thereafter, thus determining how one should separate out the data into NUGs.

The technique is repeated until all calibration grid points in the region R are exhausted. At the end of this process one has divided the region into a collection of NUGs, where multiple co-located NUGs can exist. The NUGs fully cover the region R and each NUG has statistically similar data accumulated into itself. The geometrical shape and the amount of data accumulated into such NUGs is seen to be variable since these are determined by the statistical similarity of the data allocated to a NUG.

Additionally, we also consider the method of generating NUGs based not on statistical consistency but on other conditions such as

(a) minimum number of unique neighbors observed in data accumulated from allocated calibration grid points
(b) minimum number of data vectors (NMRs)
(c) maximum and minimum NUG radius
(d) specific set of NCs
(e) specific set of NCs with power ordering

and further the method of using statistical consistency or similarity or data clustering combined with any of these other conditions.

For each so obtained NUG, a variety of parameters and functions are generated and stored to describe that NUG. These are termed the NUG characteristics and may include but are not limited to the following:

(a) ordered list of NCs
(b) functions defined on the absolute NC power levels, e.g. mean, median, k-th moment, cluster-mean etc.
(c) functions defined on the relative NC power differences, e.g. mean, median, k-th moment, cluster-mean etc.
(d) serving cell/sector
(e) TA parameter (or equivalent) if applicable
(f) individual pdf of each NC power level
(g) joint pdf of NC power levels
(h) mean and variance of NC power levels
(i) mobile orientation (indoors, outdoors, facing North or South, tilted upwards, azimuth and elevation etc...)
(j) a compact and efficient representation that enables retrieval of the calibration data NMR vectors assigned to this NUG
(k) the network state as indicated in the calibration data
(l) a confidence measure indicative of the reliability of the calibration data feeding this NUG

If a pdf is determined for the NUG, that pdf may be generated using either the Parzen technique or the method of Gaussian mixtures or some variant thereof. In addition when a need to specify the variance or covariance exists, that may be set to a value dependent on the observed variance for a particular NC power level or the observed covariance matrix for a set of NC power levels.

The location ascribed to the NUG can be any internal point within the NUG. If the NUG contains only a single calibration point, the location of the NUG could be set as the location of the calibration point. If the NUG encompasses several calibration points, the location of any one of them or the centroid of such points or some other similar measure can be used to define the NUG location. Also, in the case of multiple co-located NUGs, all such NUGs could have their assigned location set to the same value.

Invention 2: Optimal location by combining of locations derived from one or more NMR.

In a typical signal strength pattern matching mobile location system the time allowed to produce a location is such that multiple network measurement reports may be available. For example, in the GSM air standard, mobile measurements are reported at a rate of approximately 2 per second whereas the time to locate is typically on the order of 30 seconds. The invention disclosed herein is a way to improve location accuracy by combining individual locations from multiple measurement reports to produce a final combined location estimate.

Grid-based signal strength pattern matching location systems typically compute a quantitative measure of how close each candidate grid point matches with the mobile reported measurement parameters. The mobile location estimate is given by the grid point with the closest match, or a location interpolated between several grid point locations.

Since there are usually multiple measurement reports available during the time allotted to report the estimated mobile location, each measurement report can be used to generate an independent location estimate. These individual location estimates can then be averaged to produce a final estimated mobile location that is statistically more accurate than simply reporting a single individual location.

Many mobile phone location engines "fall back" to a default location based on the serving cell when it is unable to determine a grid point match location. A location status variable is used to identify the fix as a fall back. The fall back location is generally far less accurate than a fix determined by the pattern matching engine. In such a system, the location combiner omits any fall back locations and only averages or combines individual fixes computed by the pattern matching algorithm.

Generally speaking, there is a loose correlation between location accuracy (also called "fix" accuracy) and mismatch distance metric (also called "cost" value). This correlation can be exploited by flagging individual location estimates as being high cost (using a location status variable) and therefore likely to have relatively large location error. A refinement to the location combiner is to skip individual locations that exceeded the cost threshold. The resulting averaged location accuracy is thereby improved.

The correlation between mismatch cost value and fix error can be exploited further by employing weighted averaging of the individual fix locations, weighting by the inverse of their cost value, normalized by the sum of the inverses.

Another metric that could be used for weighting the contribution of individual fixes to the final averaged location estimate is the number of neighbor cells reported. For example if there are 5 individual locations to be combined, and all had 6 neighbor cells reported except 1 had only 4 neighbor cells, that one would be de-weighted in the averaging computation.

A further refinement to the location combiner invention is to identify and omit outlier individual location estimates to improve the averaged final location. To accomplish this, the Mahalanobis distance from each individual fix to the combined fix is computed. A dynamic distance threshold is computed from the median of these distances multiplied by a configurable factor. Any individual location whose distance to the combined location exceeds this threshold distance is identified as an outlier. The averaged location is re-computed with the outlier locations omitted. If weighted averaging is used, the weights are re-computed prior to averaging.

We can also make the observation that the estimated locations derived using subsets of the available NMR often differ. Consider an NMR that consists of a set of ordered (in descending magnitude) power levels, with the NCs in order being ABCDE for example. Now if the lowest power NC, namely NC=E is deleted from the NMR, the locations determined using ABCD could be different from ABCDE. Similarly, the location estimated for ABCE may differ from that for ABDE. In general, the location determined for a particular subset can be quite different from that for another subset.

It is clear that if the estimated locations derived using any possible method of mapping the NMR to a location, whether using NUGs (**invention 1**) or otherwise, all agree under all combinations of subsets, the confidence we have in the estimated location is very high. *This constitutes a Confidence Measure on the Fix*, as further described in **(invention 6)**. Thus examination of the locations derived from subsets of the NMR can provide indicators to the quality of the final location estimate. The fraction of total locations that are within a certain distance of the final location also qualifies as a confidence measure.

For every NMR, one can form the set of all subsets of this NMR. Thus in the simple example of an ordered set of NCs given by ABC, the full set of subsets is {ABC,AB,AC,BC,A,B,C}. In each case, we can derive an estimated location using any method of location. We then have a set of locations, say L . Each of the locations in L may have an associated probability or some other measure derived from the particular location method, defining a set M. It is now possible to define a variety of schemes that may be implemented on the set L and the set of associated measures on L, given by M:

(a) Compute the final estimated location by clustering the set L without any reference to the measures in M
(b) Compute the final estimated location as the centroid of a region containing the tightest cluster in L having an aggregate measure higher than some pre-set value.
(c) Compute the estimated location as the location of the NUG (e.g. centroid of the NUG) which occurs most often in L.
(d) Compute the estimated location by clustering the subset of L obtained by dropping the least power member in the NMR successively. In the given example this would be the subset {ABC, AB, A}.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 10 of 40

(e) Compute the estimated location as the subset of L obtained by successively dropping the least power member in the NMR and with weighting by the corresponding measure in M.

As an example of how one would proceed, consider that we have computed the individual marginal probabilities for each NMR component over a set of candidate NUGs. Assume that the method used is based on pdfs. Then, for every subset in L, the measure set M must contain the joint probability for the subsets of the NMR. If we take the subset AB in the previous example, we have the marginal probability for A, B and C over all NUGs. To compute the joint probability of A and B for example, we would multiply the marginal probabilities for A and B individually over the NUGs (or other locations). This generates the measure set M and then with the set L and set M defined, we can apply any of the methods in (a)-(e).

One can apply the same basic method to multiple NMRs and all of their individual subsets where every subset of every NMR is assigned its own measure in a now larger set M. Following this all of the approaches taken in (a) through (e) are applicable. In particular, one might note the value of clustering the set of locations L, a much larger set that has an associated greater potential of possessing tight clusters.

In addition, in the case of multiple NMRs, one could construct a representative NMR through a clustering algorithm on each parameter of the NMR viewed over the set of such NMRs and then apply the methods in (a) through (e) to this representative NMR.

Invention 3: Generating a location estimate using NUGs obtained over a region

This method applies to how one generates an estimated location for a mobile given a received NMR and a region R over which a set of NUGs, S has been established. As indicated in **(invention 1)**, each NUG has a series of parameters and functions characterizing it. Given a received set of one or more NMRs obtained at some unknown location, the objective is to estimate that unknown location as accurately as possible using the characterization of the NUGs over this region.

(A) Generation of the estimated location using any single NMR (drawn from the set of NMRs, if that set has size larger than unity) may be done by any of the following methods or combinations thereof:

(a) Matching the ordered list of NCs in the NMR to the ordered list of NCs in the NUG and
- Generating the estimated location as the centroid of the best cluster of matching NUGs
- Generating the estimated location as the location of the highest joint probability matching NUG
- Generating the estimated location as the (joint probability) weighted sum of the locations of the set of matching NUGs

- Generating the estimated location as the (joint probability) weighted sum of the clustered locations of the set of matching NUGs
- Generating the estimated location by combining of locations derived from NMR subsets as in **(invention 2)**

(b) If the ordered list of NCs in the NMR has no exact match in the ordered list of NCs in a NUG, consider those NUGs with an ordered list containing the ordered list in the NMR, so that the ordered list in the NMR forms a subset of the ordered list in the NUG, and proceed using any or all methods indicated in (a)

(c) If the ordered list of NCs in the NMR is not contained in the ordered list of NCs for any NUG, use the highest power subset of NCs in the NMR which has either an exact match or is contained in the ordered list of NCs in the NUG and proceed using any or all of the methods indicated in (a).

(d) Evaluate the individual pdf of each NC power level in the NMR over the set of available NUGs and compute the joint probability as the product of such marginal probabilities and estimate the location by

- Generating the estimated location as the location of the highest joint probability matching NUG
- Generating the estimated location as the (joint probability) weighted sum of the locations of the set of matching NUGs
- Generating the estimated location as the (joint probability) weighted sum of the clustered locations of the set of matching NUGs
- Generating the estimated location by combining of locations derived from NMR subsets as in **(invention 2)**

(e) Evaluate the joint probability of the NMR NC power levels directly over the set of available NUGs and estimate the location by the methods indicated in (d)

(f) Compute a distortion measure between the NUG measured parameters (mean NC power level, TA value or equivalent etc.) and the corresponding parameters in the NMR. An example of such a distortion measure is the Mahalanobis distance. The weighting in this distance over dissimilar parameters can be optimized empirically or determined by calculation. Using this measure, proceed with

- Generating the estimated location as the location of the NUG with least distortion measure
- Generating the estimated location as the weighted sum of the locations of the set of NUGs, the weights applied being some function of the distortion measure.

- Generating the estimated location as the weighted sum of the clustered locations of the set of NUGs
- Generating the estimated location by combining of locations derived from NMR subsets as in **(2)**, where the measure set M is now the distortion measure.

(g) Selecting a location by matching the NC power ordering in the NMR to the NC power ordering in the NUG / UG and additionally using an *ordering number* evaluation. The ordering number is an indicator to how many relative shifts in position occur between the NMR and the NUG /UG NC ordered power levels. For example, in the NMR we may have the label ABCDE in order for the NC power levels whereas in the NUG the ordering is BACDE which evaluates to an ordering number of 1 (a single shift). Many variations of how the ordering number is computed may be considered but each of them is a measure of the distortion in order between the NC power levels seen in the NUG / UG as compared to the NC power levels seen in the NMR. An aggregate ordering number for a set of NMRs can be obtained by combining (for example by addition) the ordering numbers for each individual NMR. The final estimated location is that NUG / UG or NUG / UG cluster with the smallest ordering number. Additionally, the ordering number may be treated as a particular distortion measure as in (f) so that the methods of (f) are then applicable.

(h) Match the serving cell/sector of the candidate NUGs to the serving cell/sector of the NMR and then proceed with the methods in (a) through (f). Thus the serving cell/sector acts as a filter prior to the operation of methods (a) through (g).

(i) Filter the candidate NUGs using the TA parameter (or equivalent such as RTT) if available for the NMR and then proceed with the methods in (a) through (g). Thus the TA parameter acts as a filter prior to the operation of methods (a) through (h). This filtering may be set wider than the actual TA computed value by a configurable parameter.

(j) Filter the candidate NUGs using the mobile orientation (indoors, outdoors, facing North or South, titled upwards, azimuth and elevation etc…) parameter applied when constructing the NUGs and then apply any or all of the methods in (a) through (i).

(k) Filter the candidate NUGs by those where the serving cell identifier and serving control channel agrees with the NMR data and then apply any or all of the methods in (a) through (j).

(l) Filter the candidate NUGs by the magnitude of the serving cell forward link control channel received signal level, applying a configurable tolerance to this parameter, as one would in the case of the TA parameter in (i) and then apply any or all of the methods in (a) through (k).

(m) Filter the candidate NUGs by eliminating those NUGs that do not have at least N (configurable) neighbor cell received signal levels in common with

the NMR and then apply any or all of the methods in (a) through (l). For example, if a the NMR contains measurements of control channel signal level from 6 NC sites, then a NUG must have stored measurements from at least 4 of the 6 NCs to be considered further as a candidate NUG.

(n) Filter the candidate NUGs by one or more of the filtering methods indicated in (i) through (m) and then apply any or all of the methods in (a) through (h).

(B) When a set of NMRs obtained at some unknown location (or locations in close proximity to each other) is available, we have the opportunity to expand the methods above to exploit the multiplicity of information. Generation of the estimated location using a set of NMRs may be done by any of the following methods or combinations thereof:

(a) Generate the estimated location for each NMR in the set of NMRs by any or all of the methods applicable to a single NMR as indicated above and
   - Determine the tightest cluster of such single NMR locations, optionally using a metric derived while locating that NMR (e.g. joint probability, Mahalanobis distance etc.) to weight the clusters.

(b) Generate a representative NMR from the set of NMRs and apply the methods of (A) to this representative. The representative NMR may be generated by
   - Obtaining a representative value for each of the NCs seen in the set of NMRs, and similarly obtaining a representative value for each of the other parameters (TA or equivalent etc.) seen in the NMRs. These representative values may be obtained as some function of the available set of values, e.g. for NC power, we could use the mean or median power.

(c) Observe transitions in any of the parameters within the set of NMRs. Such transitions can be of great value in narrowing down the applicable region for location. Most parameters are quantized and hence represent a range of location possibilities. When a parameter then changes, it is possible to infer that the region applicable is on the *boundaries of the two ranges* represented by the parameter prior to and after the change. Thus for example, the change in value of a TA (or equivalent) parameter would imply that the mobile could be located near the boundary of the two regions defined by the two values of the TA parameter. Any one of these boundaries, determined for any of the parameter changes within the set then defines a narrowing of the candidate region of location for the mobile. Parameter changes that may be observed are:

   - Changes in signal power levels with respect to a particular NC
   - Rate or pattern of dropping in and out of a particular NC signal
   - Changes in serving cell or sector
   - Changes in TA or equivalent parameter

[note application of this concept when we consider the intersections of cell coverage method]

(d) Compute a distortion measure between the NUG measured parameters (mean NC power level, TA value or equivalent etc) and the corresponding parameters of ***all*** NMRs taken collectively without reduction to representative values. An example of such a distortion measure is the Mahalanobis distance. The weighting in this distance over dissimilar parameters can be optimized empirically. Using this measure proceed with

- Generating the estimated location as the location of the NUG with least distortion measure
- Generating the estimated location as the weighted sum of the locations of the set of NUGs, the weights applied being some function of the distortion measure.
- Generating the estimated location as the weighted sum of the clustered locations of the set of NUGs
- Generating the estimated location by combining of locations derived from NMR subsets as in (2), where the measure set M is now the distortion measure.

(e) Match any one of the functions in **(invention 1)**(b) to similar functions computed for the set of NMRs by using a distance or distortion measure to evaluate the similarity between the set of NMRs and the NUG, e.g. Mahalanobis distance. In this method it may also be possible to construct a pdf for the set of NMRs and compute the similarity to the pdf for a NUG by a measure applicable to probability density functions such as the Bhattacharya distance, Kullback-Liebler divergence or other measures of similarity between probability distributions. Having generated such measures with respect to the set of candidate NUGs, we can proceed to:

- Generate the estimated location as the location of the NUG with least distortion measure
- Generate the estimated location as the weighted sum of the locations of the set of NUGs, the weights applied being some function of the distortion measure.
- Generate the estimated location as the weighted sum of the clustered locations of the set of NUGs
- Generate the estimated location by combining of locations derived from NMR subsets as in **(2)**, where the measure set M is now the distortion measure.

Invention 4: Generating a location estimate by the method of intersections

(A) Generation of the estimated location using any single NMR

This method is based on the observation that the region of validity for any one of the parameters in a particular NMR defines a region within which the mobile should be located. Consider for example the power level of a particular NC (say NC1) in an NMR. Let the value of this power level be P dBm. Now consider the calibration data, and consider the entirety of calibration data such that for every NMR in that set of calibration data, the particular NC power level is within +/- x dBm of P, that is within P-x dBm to P+x dBm. Note that every calibration data vector has an associated location. The location of each such member in this calibration data subset forms a region. Let us refer to this region as R1. Then R1 defines a region within the location space with a power constraint on NC1. This region may or may not be contiguous, and may even be empty. If it is empty, the value of x may be increased within limitation (say +/- 20dBm) until a non-empty region emerges, containing valid calibration data points satisfying (falling into the range of) the NMR power requirement is obtained. This then defines a region formed of discrete points in 2-D location space. Similar regions are constructed for each of the NCs and for all other parameters in the NMR.

Considering the ranges applied to define maximum and minimum values for each parameter, we may define a range array that contains these values. This is of the form of two vectors aggregated into an array termed the range array.

Now the intersection of these regions is determined. If a non-empty intersection occurs, the range array is modified so as to be closer to the actual NMR vector, such modification being attempted in each NC power level or other NMR parameter individually. By these means the intersection region is reduced until the smallest and yet possibly clustered intersection is obtained. The estimated location can then be obtained as either the centroid of this final region or is obtained by evaluating the pdf or other statistical measure for the calibration data within this region and thus obtaining a location, by methods detailed in any or all of **(invention 3)**

If the intersection is empty, the range array is modified to be even wider than the actual NMR vector until a feasible solution is found. If no solution is found with range array at some higher threshold (say 20 dBm lower and higher in any or all of the NCs), a subset of the NCs in the NMR is considered (preferably by first dropping the lowest power NC in the NMR) and the entire process defined here is repeated. Clearly a small value for the largest width of the NC power levels in the range array is indicative of a better fit of the NMR data to a solution that uses the available calibration data.

A distortion measure (also viewable as an inverse confidence measure) may be computed associated with the range array that generates a finite intersection region. This may be obtained as

- The largest width of any NMR NC power level in the range array
- Some weighted combination of the individual widths of the NMR NC power levels in the range array, where for example a large width in a

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 16 of 40

higher power NC carries greater weight than a similar width in a lower power NC
- The area of the final intersection region

In addition, whether or not a finite region occurs with the full NMR, all possible subsets of the NMR can be examined for their intersection regions. If multiple disjoint regions occur with different subsets, they may be treated as we would a set of NUGs / UGs (see **(invention 1)**) and evaluated for the estimated location using any or all of the methods in **inventions (1), (3).** For example we can generate a pdf for each such region, treating such region as we would have a NUG / UG as described in **(invention 1)** and then apply the techniques of location described in **(invention 3)** to determine which of the regions is most likely to be the best estimate.

(B) Given a set of NMRs, the following methods may be applied:

(a) Generate the estimated location for each NMR in the set of NMRs by any or all of the methods applicable to a single NMR as indicated above in (A) and
- Determine the tightest cluster of such single NMR locations, optionally using a metric derived while locating that NMR to weight the clusters such as the distortion measure discussed in (A) or some other measure such as joint probability, Mahalanobis distance, cluster radius, etc.
- If multiple disjoint regions occur for one or more NMRs, use the methods of **(invention 1)** and **(invention 3)** to determine the most likely estimate for the location.
- If multiple disjoint regions occur for some NMRs but not for others, use all regions with an appropriate weighting; use a distortion measure such as described in (A) and an additional weighting that allocates greater likelihood to those NMRs which generate a non-disjoint region.

(b) Generate a representative NMR from the set of NMRs and apply the methods of (A) to this representative. The representative NMR may be generated by
- Obtaining a representative value for each of the NCs seen in the set of NMRs, and similarly obtaining a representative value for each of the other parameters (TA or equivalent etc.) seen in the NMRs. These representative values may be obtained as some function of the available set of values, e.g. for NC power, we could use the mean or median. Alternatively we could consider the set of NC power levels (applicable to each NMR NC level) when viewed over the set of NMRs, and choose that NC power level which requires the narrowest range to provide a valid region. This power level is then the power level in the representative NMR.

(This method produces results different from the NUG / UG approach since calibration data that is too few in number to effectively emerge in a pdf of the NUG to which they are applied can however emerge in this scheme. This is hypothesized to be the major benefit of this method.)

Invention 5: Generating a location estimate using multiple NUG / UG constructions over the same region

One application of this method is where one uses multiple sets of NUGs / UGs constructed on the same calibration data and selects that set which, when evaluated over the methods in **inventions (1)-(4)** provides the best criteria of fit. These best criteria could include the total probability, cluster radius, Euclidean norm, Mahalanobis distance or other such parameter which is an indicator of goodness of fit. The location estimated within the NUG / UG construction which provides the best criteria of fit is declared to be the final location estimate.

In another application, one can visualize the clustering to occur not purely in the location space but in another dimension of construction space, so that if a particular location exists in the best cluster over multiple NUG constructions, that location is more likely to be the correct location for the estimate. The estimated location is then obtained by applying the methods of **inventions (1)-(4)** within that selected NUG / UG set or over all sets. Each construction method can be visualized as a layer in 3-D space with a separate set of candidate locations or clusters, associated with weights on each. These weights for example being the distortion measure, probability, etc. Now one can look for vertical combining of the candidate locations across the various constructions that form the 3rd dimension. The clustering is then a process that is viewed in each location space (which is 2-D) and in the vertical dimension that examines different constructions.

A very good location estimate can be expected to cluster well in both location space and construction space. The tightness of this cluster is then as additional *Confidence Measure* on the location estimate.

Invention 6: Estimating the magnitude of the location error and generating confidence measures

A key requirement of a geo-location system is to provide an estimate of the location error. The method discussed here discloses an invention to provide an estimate of the location error in a signal strength pattern matching location system. Associated with an estimate of the location error is also a confidence measure that provides an indication of the quality of the estimate.

Since there are usually multiple measurement reports available during the time allotted to report the estimated mobile location, each measurement report can be used to generate an independent location estimate. In addition every subset of NMRs within the aggregate NMR can also be used to determine a location estimate as discussed in **invention (2)**.

These individual location estimates are combined as in **invention (2)** or otherwise, to produce a final estimated mobile location that is statistically more accurate than the individual locations.

If the estimated location is an average of the individual locations, the degree to which the individual locations are clustered around the averaged location provides an estimate of the location error. The error estimate is computed as the average of the distances from each individual location to the averaged location:

$$\hat{e} \equiv \sum_{i=1}^{N} d_i \Big/ N$$

where

N is the number of individual locations used in computing the averaged location, and,

d_i is the Euclidean distance from the ith individual location to the averaged location

or

$$\hat{e} \equiv \sum_{i=1}^{N} w_i d_i \Big/ \sum_{i=1}^{N} w_i$$

Where w_i are a series of weights applied to the distances. These weights could for example be the probabilities derived during location, distortion function values computed during the location etc.

On the other hand, when subsets of the available NMR are also considered, the estimated locations often differ. Consider for example, an NMR that consists of a set of ordered (in descending magnitude) power levels, with the NCs in order being ABCDE. Now if the lowest power NC, namely NC=E is deleted from the NMR, the locations determined using ABCD could be different from ABCDE. Similarly, the location estimated for ABCE may differ from that for ABDE. In general, the location determined for a particular subset can be quite different from that for another subset.

It is clear that if the estimated locations derived using any possible method of mapping the NMR to a location, whether using NUGs **(invention 1)** or otherwise, all agree under all combinations of subsets, the confidence we have in the estimated location is very high. We can therefore define a confidence measure on the estimated location given by any function which increases as the number of subset locations agree with the final estimated location. An example of such a function could be the fraction of total locations that agree with the final estimated location, or the fraction of total locations that lie within a certain distance (e.g. 25 meters) of the final estimated location. In addition, one could assign weights to the locations by using the parameters or functions used in computing the location to weight the calculation of such a confidence measure.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 19 of 40

Additionally the weighting quantities referred to above such as distortion measures, pdf-s etc derived while estimating any location from either multiple NMRs or their subsets can themselves be used to estimate the location error. Empirically, from past practice and observation it is possible to correlate the magnitudes of these weighting quantities with the expected error, this relationship being established either graphically or in terms of tables applicable to the particular environmental characteristics (urban, suburban, seasonal, etc), so that given a set of weighting quantities it is possible to predict the associated error in a specific location estimate.

If the set of locations derived using the set of NMRs (including possibly all subsets) exhibit clusters, one could use the cluster separation between the highest aggregate weight clusters to define the expected error. This distance can also be seen to be an *inverse* confidence measure since the large this distance is, the greater the chance of error in case the cluster selected in the final estimate was incorrect. Further, if the aggregate weight for a distant cluster is quite small, this distance should be modified so that the distance is de-weighted by the weight of the cluster. Such a distance calculation could for example multiply the cluster distance by the ration of the weight of the selected cluster to the weight of the distant cluster. Many such variations of this fundamental idea are clearly conceivable.

It may be the case with grid-based location systems that all of the individual locations are at the same location (all located at the same grid point for example), and the resulting error estimate is zero. In this scenario, the error estimate is lower bounded by a minimum error value. This minimum error value may be simply a configurable constant that is based on the overall expected system accuracy. A reasonable value would be the 25th percentile of overall system error, or perhaps even lower.

Up to a point, the statistical averaged or weighted averaged location accuracy improves as the number of individual locations averaged increases. For example, a location that is the average of only 2 individual locations will usually be less accurate than a location that is the average of 20 individual locations. The optimal number of locations to combine depends on several factors including the speed of the mobile, and the rate of measurement reports. This accuracy dependence could potentially be used to improve the error estimate by decreasing the error estimate as the number of individual locations increases, up to the point at which the error no longer improves. The error estimate could be increased as a function of the number of individual locations when the number exceeds the accuracy improvement inflection point.

It may also occur that all of the individual locations sent to the location combiner are "fall back" locations, which are default locations based on the serving cell identification location. In this case the average spread is not a valid measure of the error estimate. A better estimate in this scenario is to use a default error estimate that is based on the expected statistical accuracy of the cell identification location. This is a function of the cell site geometry in the operating market and is determined empirically through accuracy testing.

Invention 7: Predicting the expected location accuracy

It is desirable to have an estimate of the expected accuracy when considering whether or not to deploy a mobile geo-location system in a particular market. This disclosure describes the use of a radio frequency (RF) planning model for predicting the accuracy of a signal strength pattern matching location system.

An RF software planning tool for location accuracy estimation makes use of market cell site configuration information such as cell site locations, number of sectors, sector azimuths, sector antenna beam-widths, antenna heights, antenna down-tilts, and downlink control channel transmit powers. The model also uses stored terrain map information for RF signal path loss modeling.

Making use of the above information, the model estimates neighbor cell site signal reception as a function of mobile location in the market region. The approximate statistical accuracy of a signal strength pattern matching system as a function of neighbor cell site "hearability" can be determined through prior system accuracy testing. From neighbor cell site signal hearability predications and known location system accuracy as a function of hearability, the expected accuracy of a pattern matching location system is modeled throughout the deployment region. This accuracy prediction map provides information crucial to sound planning and preparation for location system deployment.

In addition to the RF signal levels, the expected values of various other parameters can also be estimated at any given location within the region. It is then possible to derive, artificially, the expected characteristics of the NMRs that would be associated with a mobile at that location. By computing these artificial NMRs over a grid of points defined over the region, one can proceed to construct NUGs following the method indicated in **invention (1)**.

It is also then possible to simulate the behavior of the entire system, inclusive of the actual NMRs received with respect to a location and the NUGs against which these NMRs are tested to determine a location. The method by which the NUGs are used to determine a location estimate can, for example, follow **invention (3).** Given the known location and the results of the simulation (which generate an estimated location), the location error for that location can be estimated.

The location accuracy (or equivalently the location error) can thus be obtained for every point in the region. Following this it is possible to generate various measures of the accuracy such as the n-th percentile (e.g. 67th percentile) expected error or other measures of the expected error.

It is also possible to determine the expected accuracy by examination of the function describing the vector of NMR parameters. The expected accuracy is related to the rate at which the correlation between adjacent NMR vectors decays over distance. Thus one can consider the correlation as a scalar function and obtain its gradient in the 2-dimensional space. This gradient is then an indicator to the expected error: the larger the magnitude of

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 21 of 40

the gradient, the more separable the NMRs are with distance and hence the smaller the error. Similarly the smaller the magnitude of the gradient, the less separable the NMRs are with distance and hence the greater the error. The relationship of the gradient to the location error can either be determined empirically through calculation on calibration data.

Invention 8: Providing a Location Fall-back

There are occasionally scenarios in which a signal strength pattern matching mobile location system fails to compute an estimated location. This can occur, for example, when the mobile measurement report does not contain any neighbor cell measurements. In these cases, it is desirable for the system to return some sort of default "fall-back" location, rather than not reporting any fix at all. In addition, there may be situations in which the available set of NMRs for the unknown location generates a set of candidate locations that does not cluster; for example where the individual locations appear to be randomly distributed over the region. Further it may be the case that the NMR has only very few NCs reported (say only 2 for example) and the confidence in the measurement is very poor, as evinced by any computed locations measure (pdf, distortion measure, Mahalanobis distance etc. with respect to the set of NUGs). In such cases where either a location cannot be computed or the confidence we have in the candidate locations is very small, the system is still required to generate the best possible location that it can generate. The invention disclosed here is a method for reporting a default fall-back location when the location cannot be determined by the pattern matching system.

Typically, when a pattern match location failure occurs, it is because the NMR data is missing or is otherwise invalid. In this case, the only useful information about the mobile is the identification of the cell that is serving the call. From the serving cell identifier, the coordinates of the serving cell can be retrieved from the site database. A reasonable fall-back location in these cases is to return the location that is a configurable fixed distance away from the serving site at a heading along the serving sector azimuth.

For air standards in which the mobile timing advance (TA) parameter or equivalent (such as RTT) is available, this can be converted to an approximate range estimate from the serving site. In the GSM air standard, for example, the timing advance corresponds to a range from the serving site that is 553 meters multiplied by the timing advance. For example, a mobile timing advance of 4 indicates that the mobile is approximately 2,212 meters away from the serving site. The range estimate is not very precise because the quantization step size is 553 meters, but is normally accurate to within +/- 277 meters. In implementations in which the timing advance is available, the fall-back location can be enhanced by choosing the location on the serving cell azimuth at a distance from the site given by the timing advance range estimate.

If the NMR contains a Time Difference of Arrival (TDOA) with respect to two known base stations, this parameter can also be used to define a region within the cell to constrain the fall-back location. Such a TDOA, assuming the base station time offsets are

known, defines a hyperbola in the region of interest. An intersection of this hyperbola with the TA region applicable to this cell could be used as the fall-back location estimate.

An alternate default fall-back location that does not rely on the serving sector heading is possible if there is a-priori knowledge of the sector coverage density. If the sector coverage region can be determined, through drive testing, for example, then the centroid of the sector coverage region can be stored in the site database by sector for each site and retrieved as the default fall-back location when the pattern matching system fails to determine the mobile location estimate.

Invention 9: Grid Point Interpolation

Grid-based signal strength pattern matching location systems typically compute a quantitative measure of how close each candidate grid point (NUG for example) matches the mobile reported measurement parameters. The mobile location estimate is given by the grid point with the closest match. Since the actual mobile location is not constrained to lie at a grid point location, interpolation between grid points can often result in a more accurate location estimate. The invention disclosed herein is a method to improve location accuracy by interpolating between grid point locations when more than 1 grid point closely matches the reported data and are nearby the best matching grid point.

The main problems to be addressed in a grid point interpolation implementation is in identifying whether or not interpolation should be performed and, if so, which grid points to interpolate between. There are typically many candidate grid points on which the match distance metric (also called cost metric) is computed. The cost metric could be any of the measures discussed in invention (3). So, for example we could use the pdf, Mahalanobis distance between parameter vectors, ordering number between ordered NCs in the NMR and NUG etc.

Assume that the cost of each of N grid points ($N > 1$) is computed and the costs are sorted in ascending order, i.e. from best to worst match. Also assume that in a generic sense we represent the cost by C. Then, for each ith candidate, $i = 1..N$, the following cost ratio is computed:

$$C_Ratio_i = [C_i - C_{min}] / [C_N - C_{min}]$$

where

- C_i is the cost associated with the ith candidate grid point,
- C_N is the cost associated with the Nth candidate grid point, which is the maximum cost grid point (ie., the "worst matching" grid point), and,
- C_{min} is the cost value of the minimum cost candidate grid point (ie the "best matching" grid point)

Any grid points with a cost ratio that is less than a configurable threshold value are candidates for interpolation.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 23 of 40

Grid point interpolation is intended to be used to interpolate between adjacent or nearby grid points, not between grid points that are many grid points apart. Occasionally, 2 or more grid points that are widely spaced apart will pass this ratio check. To prevent interpolation across widely spaced grid points, the distance from each interpolation candidate grid point to the minimum cost grid point must be less than a configurable distance threshold.

When there are very few grid point candidates, the above cost ratio is often not a very reliable way to identify grid points for interpolation. This can be seen in the extreme case of only 2 cost values (N = 2), in which there is only 1 cost ratio that is always equal to one. For this reason, when there are fewer than a configurable number of candidate grid points (typically 4) the cost ratio is computed according to the following equation:

$$C_Ratio_i = [C_i - C_{min}] / [C_{min}]$$

This formula enables better identification of which grid points to interpolate when there are very few candidate grid points. The grid point distance check described above is also performed in this case to avoid interpolating between widely separated grid points.

Once the grid points for interpolation have been identified, weighted averaging is used to determine the final interpolated location. The weight assigned to the ith grid point in computing the interpolated location is given by:

$$Wi = \frac{\left(\frac{1}{Ci}\right)}{\sum_{i=1}^{N}\left(\frac{1}{Ci}\right)}$$

Weighted averaging is used instead of uniform weighting so that the minimum cost grid point (best matching point) exerts the most influence on the final location.

<u>Invention 10: Modification of the measured signal powers to offset the indoor/outdoor problem.</u>

Calibration data is typically collected outdoors. The primary reason for this is the far greater ease of doing so via either automated means (**Invention 12**) or manual collection along roads. While representative samples can be obtained in a given region to ascertain general relationships between indoor and outdoor data, it would be extremely time-consuming to do so indoors. Further, the issue of access to buildings makes the calibration of indoor locations even harder. Thus it is generally highly desirable to have a means of reliably locating a wireless device that is indoors even when the actual calibration data has been obtained primarily in an outdoor setting. It has often been found that indoor data takes the form of outdoor data obtained nearby with variable attenuations applied to the signal power components whereas other parameters such as the TA (or equivalent) remain unchanged.

This invention proposes several methods of adjusting the NMRs, the NUG characteristics, or both, in order to improve the accuracy of indoor location estimation of a wireless device when the calibration data is collected outdoors. When a wireless device is indoors, the received signal strengths of the serving and neighbor base stations tend to be lower than that of received signal strengths outdoors. As a result, absolute received signal strength comparisons between the wireless device and a calibration database may

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 25 of 40

result in poor location estimation accuracy. In the following methods, instead of comparing absolute received signal strengths, a comparison of relative received signal strengths, obtained by various modifications, is proposed.

In general, one may compute the NUG characteristics (those parameters associated with a particular NUG) directly with no reference to the indoor/outdoor issue. In this case it is understood that the characteristics are optimally suited for the outdoor problem. Now, given a particular NMR (or set of NMRs), the following procedure is followed:

1. Determine the optimal solution under the assumption that the NMR was generated outdoors. Compute the associated confidence measure as in Invention 6 or as detailed here. Let this be denoted by M1.
2. Determine the optimal solution for each of the three techniques T2,T3,T4, detailed below. Compute the associated confidence measures as M2,M3,M4.
3. Select that solution with the highest confidence measure or select the final location by weighting the individual solutions by the applicable confidence measure and combining as in invention 2.

The confidence measure could be the pdf, the Mahalanobis distance, a distortion measure, an ordering number parameter etc. as indicated in inventions 3 and 6. In every case where a comparison is made against a NUG, one could compare against similar quantities computed for the NUG (such similar quantities having also been included in forming the NUG characteristics in invention 1 or being computed as needed using the calibration data assigned to that NUG).

Technique T1: Unmodified NMR

In this technique, no changes are made to the observed NMR or set of NMRs. A direct comparison is made against the similar NUG characteristics. Additionally, if NUGs are not used and the method of location is different, the NMR is not modified before such method is utilized.

Technique T2: Received neighbor signal strengths relative to the serving signal strength

In this technique, the differences between the serving cell power and the neighbor cell powers are taken and these quantities replace the original NMR. Thus, if the original NMR had the form NMR=[P1 P2 P3 TA1], where P1 is the serving power, P2 is a particular NC power, P3 is a different NC power and TA1 is the Timing Advance parameter, the adjusted NMR is
NMR_adj=[0 P1-P2 P1-P3 TA1]. Now the comparison is made on this vector. Note that in this case, since we use the serving power to obtain the relative power, the serving power is not compared against the NUG or scheme in use, but is only used to make an adjustment to the NMR.

To illustrate this further, let us consider a particular implementation. Let RxLevServing_WD represent the received signal strength of the serving station's control channel measured by the wireless device at an unknown location to be estimated. Let RxLevNeigh_i_WD represent the received signal strength of the ith neighbor's control channel measured by the wireless device at an unknown location to be estimated. Let RxLevServing_DB represent the average received signal strength of the serving station's control channel stored in the database during calibration process. RxLevNeigh_i_DB represents the average received signal strength of the ith neighbor's control channel stored in the database during calibration process; (i = 1 to N, where N is the number of neighbor cells reported). Then, in this method, comparison is done over the received signal strengths of the neighbors relative to the serving station's received signal strength. i.e. comparisons are made between (RxLevServing_WD - RxLevNeigh_i_WD) and (RxLevServing_DB - RxLevNeigh_i_DB) for all neighbors measured by the wireless device.

Technique T3: Received neighbor signal strengths relative to the highest neighbor's signal strength

In this technique, the differences between the highest power neighbor cell and the other neighbor cell powers are taken and these quantities replace the original NMR. Thus for example if the original NMR had the form NMR=[P1 P2 P3 P4 TA1], where P1 is the serving power, P2 is a particular NC power with highest power, P3 is a different NC power and TA1 is the Timing Advance parameter, the adjusted NMR is NMR_adj=[P2-P1 0 P2-P3 P2-P4 TA1]. Now the comparison is made on this vector. It is also possible to make the comparisons by excluding the serving cell power or for that matter any other particular neighbor power. If the serving power is excluded, we may ignore the first and second terms in the NMR. Note that in this case, since we use the power in the second NC to obtain the relative power, the power in that NC is not compared against the NUG or scheme in use, but is only used to make an adjustment to the NMR.

To illustrate this further, let us consider a particular implementation. Let RxLevNeigh_h_WD represent the received signal strength of a neighbor's control channel (neighbor A) with the highest level measured by the wireless device at an unknown location to be estimated. This will be the first in the list of a measurement report when signal strengths are sorted descending (h = 1). Let RxLevNeigh_i_WD represents the received signal strength of the ith neighbor's control channel measured (neighbor i, where $i \neq h$) by the wireless device at an unknown location to be estimated. Let RxLevNeigh_h_DB represent the received signal strength stored in the database during calibration process for the neighbor that had the highest received signal strength measured by the wireless device (neighbor A). RxLevNeigh_i_DB represents the received signal strength of the ith neighbor's control channel (neighbor i, where $i \neq h$) stored in the database during calibration process; (i = 1 to N, where N is the number of neighbors reported). In this method, correlation is done over the received signal strengths of the neighbors relative to the neighbor that had highest received signal strength observed by the wireless device (neighbor A). i.e.

compare between (RxLevNeigh_h_WD - RxLevNeigh_i_WD) and (RxLevNeigh_h_DB - RxLevNeigh_i_DB) for all neighbors measured by the wireless device.

Technique T4: Received neighbor signal strengths relative to the average neighbor signal strengths

In this technique, the original NMR is replaced by an adjusted NMR where each signal power component is adjusted by the average signal power of some of the NC components in the NMR. One may decide to use the average of the two highest signal powers, the three highest powers, the average of all N signal powers, or an intermediary number. The adjustment reduces the power in all NMR components by this amount or subtracts the existing NMR power component from this average.

A particular implementation may now be considered. Let RxLevNeigh_avg_WD represents the average received signal strength of a number of neighbor control channel signal powers measured by the wireless device at an unknown location to be estimated. Let RxLevNeigh_i_WD represent the received signal strength of the ith neighbor's control channel signal power. Let RxLevNeigh_avg_DB represents the average received signal strength of the data stored during calibration computed over the same neighbors that were measured by the wireless device and used in computing the average for the wireless device. The same neighbor cells are used in computing the average for the wireless device and for the database. Let RxLevNeigh_i_DB represent the received signal strength of the ith neighbor's control channel stored in the database during the calibration process; (i = 1 to N, where N is the number of neighbors reported).

In this method, the comparison is done over the received signal strengths of the neighbors relative to the average received signal strength computed over all neighbors observed by the wireless device. i.e. compare between (RxLevNeigh_avg_WD - RxLevNeigh_i_WD) and (RxLevNeigh_avg_DB - RxLevNeigh_i_DB) for all neighbors measured by the wireless device. The averaging over all observed neighbors signal strength can be done either in absolute powers (mW) or in relative powers (dBm).

In addition, we propose to dynamically choose the best method applicable for specific cellular technology or terrain to increase the accuracy of location estimation. For example if method A is the best method for outdoor location estimation, method B is the best method for indoor location and method C is the best for mixed (indoor & outdoor) location estimation. If the serving cell for a call is known to be in an area where there are no buildings then method A is chosen. If the serving cell is in building then method B is chosen. If the serving cell is in an area both outdoor and indoor calls are possible then method C is chosen. In general, this can be extended to probabilistically weight the hypotheses and the derived confidence measures. Thus for example if the probability that the mobile is outdoors is p1 and the confidence measure is c1, the applicable weighting could be c1*p1, the corresponding product for outdoors may be c2*p2. It is then possible to make a maximum likelihood choice of the indoor/outdoor hypotheses options and the location jointly. A similar approach applies to choosing different methods based on air standard.

Invention 11: Refinement of ground truth using a street database for more accurate calibration database generation

With this proposed method, ground truth locations observed from a device (for example a GPS receiver) are refined based on a Street Database for more accurate generation of a calibration database.

Determining ground truth accurately is an essential component of generating a calibration database. Without highly accurate ground truth established, the calibration database will have significant errors which will be reflected in the lack of accuracy of the final application to location estimation. Any device that is used to retrieve the ground truth can have some degradation or drop-outs. In the case of a GPS receiver, this could be due to low satellite visibility or high dilution of precision (DOP). Additionally most vehicles that are set-up to generate a calibration data base use a dead-reckoning device. Such devices attempt to calculate the location of the vehicle over short distances where the GPS location is not available, doing so using the last accurate GPS location and various inputs from the vehicle control system. These dead-reckoning schemes generally have on order of error much larger than the errors expected with accurate GPS location. For all of the above reasons, it is imperative that the ground truth calculated and stored in the calibration database be improved to minimize such errors. The methods are proposed with the intent of improving the accuracy of ground truth in the creation of a calibration database.

One can pose the general problem of how to correct an obtained set of locations. One has an obtained set of points, each of which is a location obtained by some means in a geographical area that contains multiple streets with mutual intersections. The problem then is whether this set of locations can be improved in its accuracy given some other information. In this context one method that is applicable is the use of a Street Database.The Street Database is a highly accurate database containing latitude and longitude information for points on a map, and additionally provides ancillary information such as the direction of one-way streets etc.

Generally, the first step in correcting an obtained map of locations using a Street Database may be to determine an optimal overlay of the obtained locations on the Street Database. Following this, one may proceed to determine for each ground truth retrieved from a device, and provided the retrieved point is not on the street, the closest point in the street database. Many such methods of implementing such an overlay may be available. Once this overlay is found, the ground truth retrieved from a device is replaced with the ground truth derived from a Street Database using various methods, some of which may be known. A particular method that may be used is for each ground truth retrieved from a device and where this point is not on the street, to find the two closest points in the database and then use interpolation to determine a third point which is in between these two closest points. The ground truth of this third point then replaces the ground truth that was retrieved from a device. Another method is to use the history of ground truths retrieved from a device, the direction that the vehicle is moving, and recent turns it took,

the most likely street is determined. Then ground truth retrieved from a device is replaced with the ground truth of the closest point on that most likely street. This is similar to a recalculation of the dead-reckoning result and can be used when the dead-reckoning component on the calibration device/vehicle is unavailable or know to be in error. Additionally, if only a GPS receiver is used, ground truths that have the number of satellite visible less than a threshold or DOP more than a threshold, and distance from last valid GPS reading in excess of some threshold are excluded from the calibration database.

This invention claims the use of any of these methods indicated here and/or any other existing and known method of correction of a set of locations to the specific problem of correcting a set of data vectors where each data vector (calibration data point) has an associated location (each data vector with say N components has one of its components as the location where the other N-1 components apply). Thus each calibration data vector, each of which has an associated location, has this location corrected by any general method of correcting a set of locations using a Street Database.

Invention 12: Generating a calibration database using autonomous T&M equipment

The motivation for this method is the observation that autonomous Test and Measurement (T&M) equipment can be placed on public transportation vehicles such as buses or taxi cabs, or on other highly mobile devices such as FedEx, UPS etc. vehicles, or other types of vehicles that travel often within the calibration area. With this method, the calibration effort can be reduced greatly and calibration database can be updated constantly. Such a device would have the means to observe NMR data, just as one would if a mobile device were placed on such a vehicle.

Such T&M equipment will have a wireless terminal that is capable of measuring received signal strengths of serving and neighbor cells. T&M equipment will also have a device, such as a GPS receiver that computes the ground truth location of the wireless terminal. This Autonomous T&M Equipment (ATME) will have the capability of storing received signal strengths of the serving and neighbor cells, some network information such as CGI, BCCH, BSIC etc and corresponding ground truth location. Ground truth may be refined during post-processing by aligning the locations with streets using highly accurate street coordinate maps. This T&M equipment will also be capable of sending stored data to a server using available wireless data transfer technology such as GPRS.

The autonomous T&M equipment would be in constant communication with a T&M controller unit using some wireless data transfer technology as indicated earlier. The T&M controller could be examining the statistical sufficiency of the data it has available for the current location of the ATME and use tests of the statistical sufficiency to determine whether the new data provided by the should be added to the existing calibration database. In addition the T&M controller may be linked to a NUG generator (**invention 1**) so that NUG generation (or augmentation or refinement) can proceed in parallel with the data acquisition from the ATME. In case statistically sufficient and recent data is available for the currently constructible NUG, there would be no reason to

overload the existing calibration database with further data for that location. Thus a continuous examination of the reported data can allow for selective and judicious insertion of such data into the calibration database. The NUGs will be similarly updated only as needed. Depending on the requirement for data from a particular location, one could also envision turning the ATME off when for example the vehicle containing the ATME is parked or otherwise immobilized or is traversing a region for which we have good recent data already available.

The ATME can also be used to alert the T&M controller to changes in the wireless network. Changes such as a site going down, a new site being enabled or the transmit power changing at an antenna may be recognized more readily by the T&M controller when a continuous data stream is arriving from the ATME than if one were to rely on information communicated by network operators to the location system. Thus the ATME serves as an early warning device to the pattern matching location system.

In addition, one can conceive of a Fully Autonomous T&M Device (FATMD) which determines its future position based on communication with the T&M controller, and where the T&M controller is communicating with the NUG generation process. In this embodiment, consider the FATMD as currently in a particular location. The FATMD passes back available NMR data to the T&M controller. This NMR data has an associated location time-stamp, a velocity stamp and a range of other possible parameters in addition to the NMR parameters. The controller can signal to the FATMD when it no longer needs data at that particular location, thus allowing the FATMD to move out of the current location. Depending on the rate at which the reported data statistics change, the T&M controller can optionally inform the FATM what desirable speed of current travel it can use as a maximum setting. With this additional information, an FATMD could be seen to either linger for longer periods in certain locations or move briskly out of locations where the reported data is statistically similar. As a result, the dwell-time for such an FATMD in a particular region could be optimized so that the device does not unnecessarily waste time in a region where extra NMR data is not needed and on the other hand does not spend too little time in a region where more NMR data is needed.

Some of these features of a FATMD can also be applied to the case where such features are implemented by a human driver of the equipment. In such a situation, the human driver can be instructed by the T&M controller using voice commands to slow down, speed up, turn at the next intersection etc. Further in either the case of a human driver or not, regions where data insufficiency or statistical paucity exists can be flagged as regions where a quickest return to that area is needed. An example of such may be in a traffic situation where the driver (human or not) has no option but to keep moving even though the data requirement is that it linger. Such examples are commonplace in a high traffic environment if one is to not cause a traffic jam or cause inconvenience to other drivers. Thus in such a situation, the driver may continue to circle a block until the T&M controller indicates to the FATMD driver that statistical sufficiency has been met.

In general the division of labor between fully automated components within this scheme and human enablers of the same action can take various forms ranging from the fully

automated case to the case where the reporting of a data NMR is done manually. This invention covers this entire range of implementations.

When statistical sufficiency or data sufficiency is met in a particular region, the FATMD can randomly proceed to a next region or be guided to a particular region by the T&M controller which has information on where the data is insufficient or where particular NUGs need to be built or refined. It may be deduced from the above that in general such an AFTM will spend less time per unit area in a rural setting where the statistical nature of the NMRs changes slowly as opposed to an urban setting that has vigorous dynamic NMR changes over short distances. Thus it is possible to minimize the total time within which a particular region can be calibrated for the purposes of a pattern matching location scheme. One should contrast this with the blind acquisition of NMR data by a device which has no knowledge of whether the data it is reporting is useful, needed, or in the other extreme, excessive, to note that the proposed method is a more intelligent use of resources targeted to the eventual problem of location estimation.

Invention 13: Filling holes in calibration data

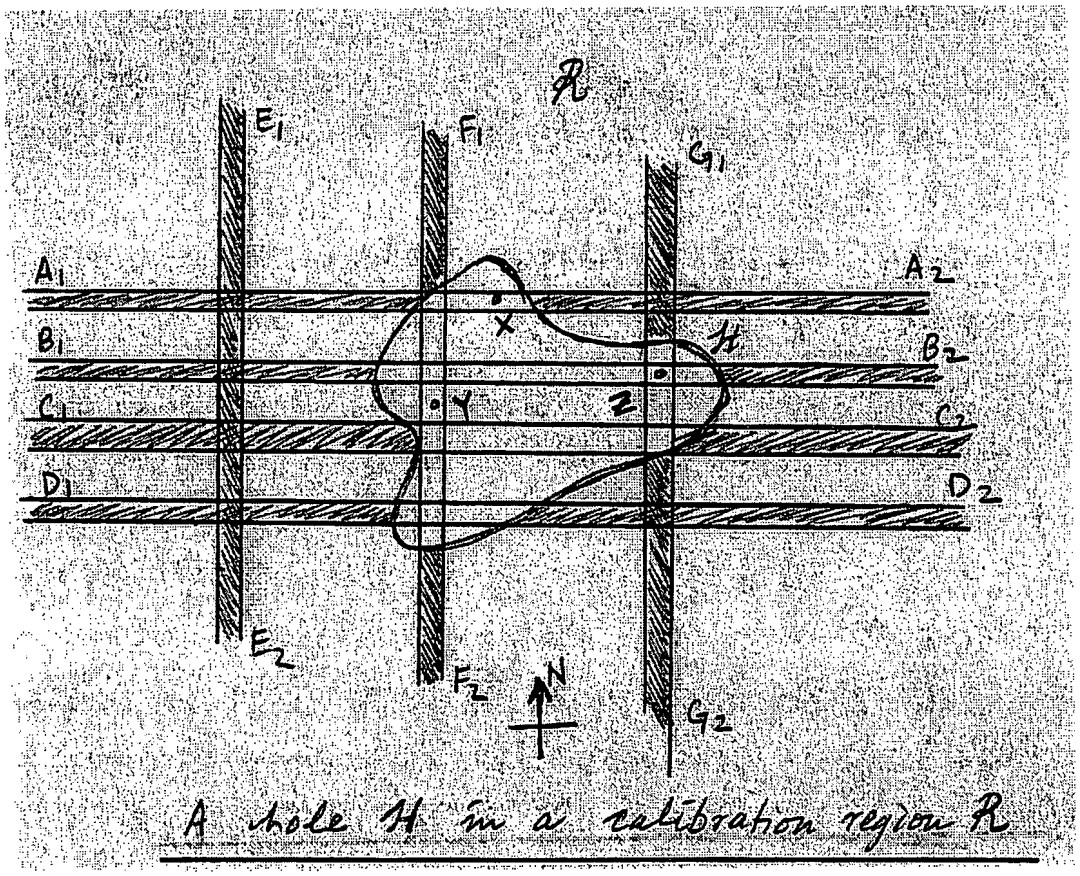
Consider the examination of a previously completed calibration of a cellular network for the purposes of mobile location. Each calibration point is associated with one or more NMR data vectors and an associated location (ground truth). In all likelihood the collection of this data would have proceeded by utilization of a drive test vehicle that either autonomously (invention 12) or otherwise navigated through a region R acquiring data.

It is likely often the case that such a drive test vehicle is incapable of locating itself in every possible candidate location that a mobile could find itself in. For example, locations such as inside buildings, pedestrian walkways and malls etc. and in general any area not accessible to vehicular traffic would fall out of the navigable region. Though some of these inaccessible regions may be later calibrated manually, the effort required to do so could be prohibitive.

As a result of having such sub-regions where calibration was not possible, the resulting calibration data for the region R may have what are termed holes. Holes in this context refer to regions (generally small) where for one reason or another, calibration data is not available. On the other hand, such holes remain viable locations for a mobile, so that there is a non-zero probability that a mobile could be in such a hole. This makes it imperative that the location estimation system "fill" these holes in a sensible manner.

If one carefully studies the variation of a NC signal power over a region, one observes that the variation in any direction can be modeled by a smoothly varying function which typically decays with distance. In particular it is very revealing to observe the variation of the signal strength along grid points along streets in the region. Along such streets one finds that the signal exhibits great continuity on average. It is important to emphasize the word *average*. The signal may experience large fluctuations due to blockage by building etc. but the average (over distance) fits a smooth curve.

This smooth curve fitting property of the signal average along streets is exploited in this invention to fill holes in the calibration data. The attached picture shows a hole in a calibration database with the street network marked up. As an example consider that there are 4 NCs (nc1,nc2,nc3,nc4) visible outside the hole, with the 4th NC (nc4) available only on the west side of the hole.



To illustrate the method consider that we wish to determine the NMRs that would exist at the points X, Y and Z in the figure.

Point X: One would examine the available data for nc1 outside the hole and along the street A1A2. A curve that best fits this data would be obtained by any curve-fitting means. This function/curve would represent the variation of nc1 with distance along the direction A1A2. It is then possible to estimate the expected value of nc1 at the point X. Identically, one would proceed with NCs nc2, and nc3 to obtain the estimated values at X. Now since X is approximately mid-way between the extremities of the hole along the direction A1A2, we could either assume that the NMR at X contains a reading for nc4 or not. We may wish to cover both hypotheses. In the one case we would proceed exactly as for the other NCs but in this case extrapolate east-ward along A1A2 from the west most edge of A1A2. In the other case we would set NC4 as absent in the NMR at X. In either case we have now established an NMR at point X and filled this point in the hole, even possibly with two candidate NMRs that differ only in the presence or absence of NC4.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 33 of 40

Point Y: One would examine the available data for nc1 outside the hole and along the street F1F2. A curve that best fits this data would be obtained by any curve-fitting means. This function/curve would represent the variation of nc1 with distance along the direction F1F2. It is then possible to estimate the expected value of nc1 at the point Y. Identically, one would proceed with the NCs nc2, and nc3 to obtain the estimated values at Y. Now since Y is much closer to the western border of the hole, we may make the assumption that NC4 is present in the NMR at Y and proceed exactly as for the other NCs.

Point Z: Since point Z is at the intersection of two streets (or the hypothetical extension of two streets since there may not actually be such a street within the hole) we have added leverage in making an estimate. One would proceed exactly as before for all of the signals nc1,nc2,nc3 except now we would curve fit along B1B2 as well as G1G2 thus forming a best joint estimate of the NC values at Z. Since Z is proximal to the eastern border of the hole, we may decide that NC4 is absent in the NMR at this point.

By such general means we can then proceed to fill in a hole in a calibration region R by curve fitting, interpolation and extrapolation. We can thus estimate the NMRs at every point of interest within the hole where such points are located on extensions of streets. Points not on streets may be treated with general interpolation between points adjacent and located on the extension of streets.

Invention 14: Distortion Measures

This invention applies to how one generates an estimated location for a mobile given a received NMR and a region R over which a set of NUGs, S has been established (**invention 3**), and in particular focuses on the use of a distortion measure to evaluate the candidacy of a particular NUG. As indicated in **invention 1**, each NUG has a series of parameters and functions characterizing it. Given a received set of one or more NMRs obtained at some unknown location, the objective is to estimate that unknown location as accurately as possible using the characterization of the NUGs over this region. As indicated in **invention 3**, one method of doing so is to determine a distortion measure between the available received NMR and the NUG characteristics.

The generic term "cost" may be used more colloquially to refer to such a distortion. The methods listed here explain different ways of computing the mismatch distance, distortion measure between the mobile reported measurements and a candidate grid point's stored measurement data. The cost ost value is inversely proportional to an increasing function of the probability that the mobile is located at (or very close to) that grid point (NUG). For location estimation, the grid point with the minimum cost value may be chosen or grids points may be interpolated as explained in **invention 9**.

The generic form of a distortion measure would be a function combining the values of all parameters in the NMR and all corresponding parameters in the NUG characteristics, with the distortion measure generally increasing as the mismatch between any of the

parameters (in the NUG vs. the NMR) increases and vice versa. A NUG parameter is in general as indicated in **invention 1**, a representative value obtained by a variety of means.

For example, a particular cost value may be computed using the Mahalanobis distance expressed by the following formula:

$$COST = \alpha\left(TA_{rpt} - TA_{cand}\right)^2 + \sum_i \left[\left(\frac{RxLevDiff(i)^2}{MAXDIFF^2}\right) NCCU\right]$$

Where it is seen how one may combine dissimilar quantities (in this case power levels and Timing Advance (TA) values using the Mahalanobis distance. In this expression, the variables are:

α: 1 or 0. this controls if TA differences are included in the cost value or not. For example it is 1 for the GSM specification and 0 for the iDEN specification.

TA_{rpt}: TA for the NMR.

TA_{cand} : TA for the candidate grid point in calibration database; possibly a representative value.

NCCU: Neighbor cell cost unit. Increasing NCCU increases the cost penalty for RxLev difference relative to the cost penalty for TA difference.

MAXDIFF: Configurable parameter that limits the cost incurred for difference of signal strengths. It is nominally set to 20 dB. RxLev differences that exceed this threshold do not incur additional cost penalty. The main reason for imposing this limit is so that this maximum cost penalty value can be applied in the situation where the grid point does not have a measurement of a neighbor cell that was reported by the mobile.

i: Index to neighbor or serving cells. If only neighbor received signal strengths are used, and there are 6 neighbor cells (generally this could be a non-negative integer N) reported, then i = 1 to 6. If in addition, serving signal strength is included then i = 1 to 7.

RxLevDiff(i): Difference in RxLev for the ith neighbor (or serving). There are different methods of calculating the RxLevDiff.

RxLevDiff(i) Method 1

Compares (serving RxLev – ith neighbor RxLev) between NMR and candidate point. (Deviation of ith neighbor RxLev from serving cell RxLev comparison) Therefore

$RxLevDiff(i) = (RxLevServ - RxLevNeigh(i))_{NMR} - (RxLevServ - RxLevNeigh(i))_{CND}$
for i = 1:6

RxLevDiff(i) Method 2

Compares (ith neighbor RxLev) between NMR and candidate point. (ith neighbor absolute RxLev comparison) Therefore

$RxLevDiff(i) = (RxLevNeigh(i))_{NMR} - (RxLevNeigh(i))_{CND}$

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 35 of 40

for i = 1:6

RxLevDiff(i) Method 3
Compares (1st common neighbor RxLev – ith neighbor RxLev) between NMR and candidate point. (Deviation of ith neighbor RxLev from 1st neighbor RxLev comparison) Therefore

$RxLevDiff(i) = (RxLevNeigh(1) - RxLevNeigh(i))_{NMR} - (RxLevNeigh(1) - RxLevNeigh(i))_{CND}$
for i = 2:6

RxLevDiff(i) Method 4
Compares (average neighbor RxLev – ith neighbor RxLev) between NMR and candidate point. (Deviation of ith neighbor RxLev from average neighbor RxLev comparison) Therefore

$RxLevDiff(i) = (AvgRxLevNeigh - RxLevNeigh(i))_{NMR} - (AvgRxLevNeigh - RxLevNeigh(i))_{CND}$
for i = 1:6

RxLevDiff(i) Method 5
Compares (average RxLev of the serving and neighbors – ith neighbor or serving RxLev) between NMR and candidate point. (Deviation of ith neighbor or serving RxLev from average RxLev comparison) Therefore

$RxLevDiff(i) = (AvgRxLev - RxLev(i))_{NMR} - (AvgRxLev - RxLev(i))_{CND}$
for i = 1:7

In this method serving cell's signal strength is also included in the average RxLev computation and also in comparing it with the calibration database. Therefore i ranges from 1 to 7 (one serving and six neighbors).

<u>Invention 15: Method for adapting to a network change</u>

A wireless network is subject to various adjustments and changes over time. Even though such changes may not be an every day occurrence, it is possible that on a diurnal basis certain components are adjusted, installed or removed. For example, in certain locales the maximal wireless traffic may be in a certain part of the day and the network may need to adapt to handle such traffic. At other times it may be that there is very little wireless traffic in a certain region (e.g. a mall between the hours of midnight and 8:00 am), so that at such times it would be best to allocate system resources elsewhere. Thus, in general the wireless network is best considered as a dynamic entity.

Also it may be necessary to distinguish between known (anticipated) diurnal changes that the network operator and the location system operator are in mutual knowledge of and changes that are sudden such as an immediate issue such as a failure at a particular sector etc. (unanticipated changes). One could have a procedure in place to handle the known

diurnal or weekly variation; a different approach is needed for the sudden/un-anticipated variations.

When some aspect of the network changes, and where this aspect has an impact on the capability of our location technique, a desired objective is that the location system continues to function with minimum degradation. In addition, the objective is that the re-calibration of the network is achieved with minimum effort and in the most efficient manner possible. This invention offers quick and simple methods of modifying the calibration data for a network that does not require a re-calibration effort. That is, we offer methods of modifying the existing calibration data such that the data continues to be valid for location purposes, and where this modification does not require one to physically re-calibrate any part the network. What is claimed includes methods that minimize human interaction for the re-calibration of affected areas in case of a network change. This method assumes knowledge of the current calibration database, current network configuration, and proposed new network configuration, such information being provided on the communication link between the location system operator and the wireless network operator.

1. **Method applicable to an antenna modification**
   If one or more antennae at a sector are changed, this method describes how one would correspondingly modify the calibration data. To do so we introduce the concept of a Sector/Cell NC RF map. This map indicates the power levels at each calibration point corresponding to a particular transmit power at the sector wireless antenna. Alternately, it tells us the relative power levels at each calibration point when a particular antenna was used. This information can be derived from the existing calibration data. In addition, such a map can also be obtained by the use of an RF planning tool where various attributes of the operating environment provide input to software which predicts the RF signal power levels at various point in the network. One can then obtain the relationship between the Sector RF map derived from the calibration data and the RF map derived from the planning tool to determine the relationship between the two. This relationship may not be a constant scalar but rather, in the general case, a set of scalars, each applicable to a particular calibration point. Now if the antennae have changed, it is possible to establish the relationship of the antenna patterns using the RF planning tool and then use this relationship coupled to the computed scalar set to determine the expected RF signal power when the antenna modification is implemented.

   Each calibration point has an associated calibration data vector (invention 1) and in each such vector a particular element refers to the NC signal power of a particular sector antenna. Thus a one-to-one replacement of the pre-existing value with the newly computed value can be made.

Geoscope Exhibit 2029
Apple v. Geoscope
IPR2024-00259, Page 37 of 40

In the extreme case of the antenna being powered down or removed, all associated elements in all calibration data vectors are then set to indicate the absence of signal (a very low dBm level or deletion of the NC signal)

This method also includes the case of a heading change on an antenna. In such a case one could once gain use the relationship of the Sector/Cell NC RF map to the RF map derived from the RF planning tool in the rotated position to determine the replacement values for the NC signal power in the calibration data vectors. In a simpler method one could also simply rotate the existing elements in the 2-D region and assign that value to the calibration data vector located at the rotated position. In this simpler method, if the transmit power level of a sector is changed by X dB then calibration data is adjusted by X dB in the database, or if the heading is changed then the calibration data is rotated accordingly etc.

2. **Method applicable to a power modification with impact to serving cell/sector**
A power modification can be treated by the same method as in (1) but here in addition we consider how to modify other parameters different from signal power. For example, consider that we have obtained the newly computed NC signal power at a particular calibration point. We also know the pre-existing serving cell/sector power at this calibration point. Now if the newly computed NC signal power is in excess of a threshold value higher than the power for the serving cell/sector and assuming this serving NC is different from the one that has been modified, it is necessary to change other parameters. Such parameters include (a) the identified serving cell/sector (this could now be set to the NC sector/Cell which has been newly computed), (b) Timing Advance (TA) or similar parameter that is associated with the serving cell/sector, and (c) other possible parameters that are affected by a change in the serving cell/sector and NC signal levels. In these cases, the parameter change can be calculated based on the new serving cell/sector. As an example the applicable TA parameter for the calibration data point can be calculated based on the known locations of the calibration data point and the new serving cell/sector.

3. **Method applicable to an additional channel assignment**
Additional channels may be applied at a particular sector /cell for the purposes of handling variations in user density (for example a diurnal variation as described in the introductory paragraph). When such a new channel is applied at a particular sector/cell, this may impact the RF signal power distribution for that NC signal power depending on the frequency allocation for that channel. Once again one can utilize the RF planning tool as a device to establish relationships between the existing case and the case when the frequency is modified, to determine the corrections required on the RF signal power elements in each calibration data vector. The power must also be adjusted following the means indicated in 1.

4. **Method applicable to identifying regions for re-calibration**

This case applies to any one or more network changes. In any such case, one examines each calibration data vector available in the calibration data base to determine whether this network change has an impact on the elements of such vectors. For example, if the NC power changes for some cell/sector and this NC signal power is contained in the calibration data vector, we know that this vector is affected by such a change. Having identified such impacted calibration data vectors, the locations of such vectors are aggregated into a set. This set of locations then constitutes a region that may be identified for re-calibration using any possible method including invention 12 for example. In addition, when a sector/cell signal power is increased, calibration data vectors that may have previously indicated the absence of this NC signal may now be activated. To that end it is preferable that all calibration data vectors contain dummy fields set to the lowest possible dBm value for every NC signal in its proximity; this then ensures that this NC signal power is incremented appropriately.

5. **Method applicable to re-computation of NUGs**
This method identifies those NUGs which need to be recomputed as a result of the network change. The manner of determining this is via the calibration data. If any calibration data has experienced a change due to the methods of 1 through 3, every NUG containing such calibration data is identified and then the methods of invention 1 are applied to the calibration data within such identified NUGs. This results in NUGs that are valid for location purposes subsequent to the network change.

6. **Method applicable to computations in affected regions**
Having identified the calibration data vectors and NUGs affected by a network change, and understanding that the methods of 1 through 5 are inferior to an actual re-calibration of such affected regions, this method allows one to apply a reduced confidence to those NUGs when computing a location. Multiple avenues of doing so are available. For example one can lower the probabilities in the NUG pdfs or one could increase the distortion measures computed against such NUGs when making a location estimate. A further possibility is the selective deletion of affected parameters from consideration in the computations. In this case, if a particular parameter is affected, this parameter is deleted in the NUG generation process. The NUG thus acts as if this parameter does not exist or is at a minimum threshold thus reducing its probability in for example a pdf. The location system is then capable of including such NUGs in its location estimation task. Finally and in the most drastic case, one could set the confidence characteristic for such NUGs to zero and eliminate these NUGs from consideration. Alternatively if the affected regions encompass nearly the coverage areas of particular sectors or cells, one could place the location system in CID or E-CID mode for these selected sectors or cells.

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