(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 May 2007 (03.05.2007)

PCT

(10) International Publication Number
WO 2007/048177 A1

(51) International Patent Classification: *H04Q 7/34* (2006.01)

(21) International Application Number: PCT/AU2006/001577

(22) International Filing Date: 24 October 2006 (24.10.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2005905863 24 October 2005 (24.10.2005) AU
2005906105 4 November 2005 (04.11.2005) AU

(71) Applicant *(for all designated States except US)*: **SEEKER WIRELESS PTY LIMITED** [AU/AU]; Suite 15, 924 Pacific Highway, Gordon, NSW 2072 (AU).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **SCOTT, Craig, Andrew** [AU/AU]; 18 Scott Street, Mortdale, NSW 2223 (AU). **MACNAUGHTAN, Malcolm, David** [AU/AU]; 23 Reservoir Road, Pymble, NSW 2073 (AU).

(74) Agent: MADDERNS PATENT AND TRADE MARK ATTORNEYS; Level 1, 64 Hindmarsh Square, Adelaide, S.A. 5000 (AU).

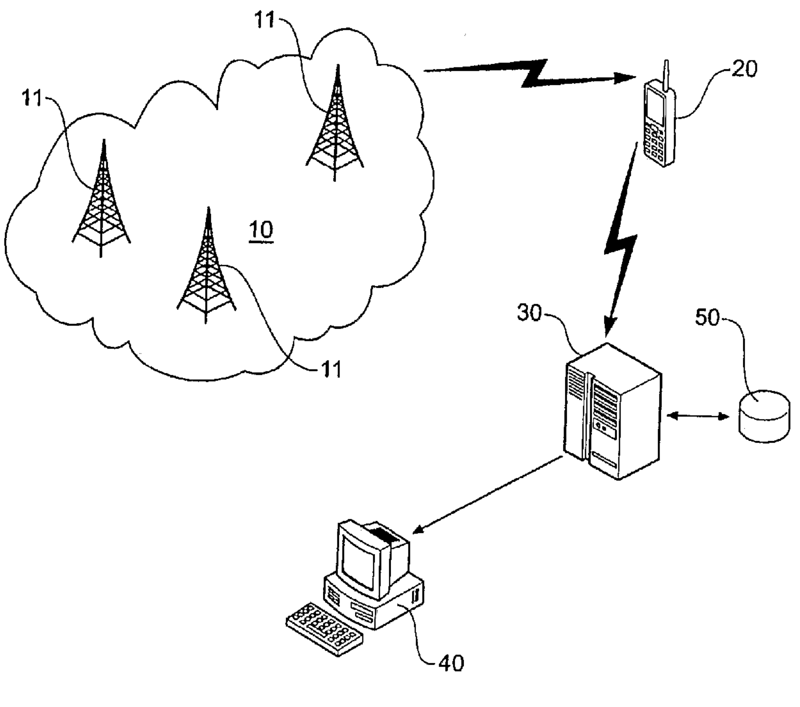
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: DETECTION IN MOBILE SERVICE MAINTENANCE



(57) Abstract: Disclosed is a method and system for detecting inconsistencies between a radio communications network and a network database. In one form, measurements from the network are provided by mobile radio terminals. The measurements are then compared with corresponding data on the network database to determine whether there is an inconsistency. The methods described may be used in the management and maintenance of the network.

WO 2007/048177 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DETECTION IN MOBILE SERVICE MAINTENANCE

Technical Field

The present invention relates to mobile communication networks and to their management.

Priority Documents

The present application claims priority from:

Australian Provisional Patent Application No. 2005905863 entitled "Mobile Service Maintenance" filed on 24 October 2005. ; and

Australian Provisional Patent Application No. 2005906105 entitled "Profile Based Communications Service" filed on 4 November 2005.

The entire content of each of these applications is hereby incorporated by reference.

Incorporation By Reference

The following co-pending patent applications are referred to in the following description:

- PCT/AU2005/001358 entitled "Radio Mobile Unit Location System";
- PCT/AU2006/000347 entitled "Enhanced Mobile Location Method and System";
- PCT/AU2006/000348 entitled "Enhanced Mobile Location"
- PCT/AU2006/000478 entitled "Enhanced Terrestrial Mobile Location"
- PCT/AU2006/000479 entitled "Mobile Location"
- PCT/AU2006/001479 entitled "Profile Based Communications Service"

- Co-pending International Patent Application entitled "Mobile Service Maintenance Management" filed concurrently herewith and claiming priority from Australian Provisional Patent Application No. 2005905863
- Section 2.7 of Mobile Radio Communications 2nd Ed. Editors Steele and Hanzo. ISBN 047197806X,J. Wiley & Sons Ltd, 1999
- Section 5.1.4 of "Radio Frequency (RF) system scenarios" 3GPP TR25.942
- Section 3.2 of "Evaluation of Positioning Measurement Systems", T1P1.5/98-110).

The entire content of each of these documents is hereby incorporated by reference.

BACKGROUND

Radio communication networks often use information representing certain characteristics or parameters of different parts of the network. One example of an application that uses this information is a mobile radio location system. Some mobile radio location systems operate by using radio measurements to estimate the location of mobile terminals relative to the known locations of the radio network access points. For the special case of cellular mobile phone location systems these access points are the cells.

A location system which estimates the location of a mobile terminal relative to one or more radio network access points requires knowledge of the relevant characteristics of those access points. For example, in a coarse cell identifier based mobile cellular location system, the relevant characteristics typically include the unique identifier for the cell and the geographical coordinates at which the cell is situated.

More accurate systems such as those which also incorporate radio signal measurements in the calculation process require additional configuration information. This typically includes transmitted power, antenna gain and antenna orientation.

The performance of such systems is strongly dependent on the integrity of the database containing this network configuration information. This dependence increases in systems promising greater levels of spatial resolution or accuracy. In an ideal scenario, the configuration of the cellular network will match the network database. In such a scenario a location system would only need to cope with changes to the network configuration which would be notified via an update to the network database. Experience has shown however that typically the configuration information is poorly maintained, distributed across multiple databases and exhibits many errors.

Reasons for discrepancies between the supplied database and actual configuration may lie with the network database or with the network configuration or both. The database may be at fault due to errors such as typographical errors, especially the transposition of numbers, during data entry; problems with the process used to collect and collate the network data; and failure to propagate network configuration changes to the database. Conversely the network configuration may not be as intended due to errors such as typographical errors when entering configuration details and failure to configure one or more planned network changes.

A further problem for operators is that the network configuration is not static. Opportunities for inconsistencies to arise between the network database and deployed configuration occur throughout the life of the network. The network configuration changes when sites are added to increase capacity and/or coverage. Changes also occur when cells are decommissioned. Mobile cells (referred to as Cells-On-Wheels) can be temporarily setup to support the temporary capacity increases required to support events such as significant sporting events and outdoor music concerts. These temporary additions and deletions to the network can last for hours and in some cases days. The configuration may change temporarily when there is a cell not operating due to scheduled maintenance, equipment failure, or power failure. The network also changes when technicians retune the network to improve performance or to adapt to changes due to reasons discussed above.

Network database errors lead to corresponding errors in the operation of the location-based system and associated services, in some cases leading to unacceptable service quality for subscribers. Network operators have no means of validating that the network is configured as planned other than to perform drive tests around the network with radio monitoring equipment. The cost of updating the database so that it is continually up-to-date represents a significant operational burden for the service provider.

It is an object of the present invention to detect errors and/or inconsistencies between a configured network and corresponding network databases.

SUMMARY

In one aspect of the present invention, there is provided a method for detecting an inconsistency between a radio communications network and a network database, the method comprising:

receiving from a mobile radio terminal in the radio communications network, at least one measurement of at least one parameter from the mobile radio communications network;

comparing the at least one measurement with corresponding data in the network database; and determining that the at least one measurement is inconsistent if the at least one measurement is different to the corresponding data in the network database.

In one form, the method further comprises the step of calculating a metric associated with the at least one measurement using data from the network database, and comparing the calculated metric with a threshold.

In another form, the method further comprises determining that the at least one measurement is different to the corresponding data in the network database if the calculated metric exceeds the threshold.

In another form, the method further comprises making a hypothesis that a parameter of the mobile radio communications network is not present in the mobile radio communications network even though data in the network database indicates that the parameter is present.

In a further form, the method further comprises, if the at least one measurement does not contradict the hypothesis, considering data that supports the hypothesis.

In a further form, the method further comprises considering data that supports the hypothesis.

In one form, the step of considering data that supports the hypothesis comprises determining whether the mobile radio terminal is in a given zone.

In another form, if the mobile radio terminal is determined to be in the given zone, the method further comprises comparing the at least one measurement with data in the network database corresponding to one or more expected measurements that would be expected to be obtained by the mobile radio terminal in the given zone.

In another form, the method further comprises determining that there is an inconsistency between the radio communications network and the network database if the step of comparing the at least one measurement with data in the network database corresponding to the one or more expected measurements indicates a difference.

In a further form, the method further comprises accumulating a plurality of measurements over time and determining that there is an inconsistency between the radio communications network and the network database if the difference between the accumulated measurements and the one or more expected measurements exceeds a predetermined threshold.

In one form, the hypothesis is that the radio communications network contains a non-operational cell.

In another form, the at least one measurement is received from the mobile radio terminal using spare capacity in an already established communications session.

In another form, a plurality of measurements are received from a plurality of mobile radio terminals within the radio communications network.

According to another aspect of the present invention, there is provided a network processor in a radio communications network having at least one radio parameter, at least one mobile radio terminal, and a network database, the network database storing data corresponding to the at least one radio parameter, the network processor comprising:

a receiver for receiving from the mobile radio terminal in the radio communications network, at least one measurement of the at least one parameter;

a comparator for comparing the at least one measurement with the corresponding data in the network database; and

a means for determining that the at least one measurement is inconsistent if the at least one measurement is different to the corresponding data in the network database.

In another form of the present invention, there is provided a radio communications network comprising a network processor according to the previous aspect of the present invention.

According to another aspect of the present invention, there is provided a method for detecting a non-operational cell in a radio communications network, the method comprising:

receiving at least one measurement, including data relating to at least one cell, from a mobile radio terminal in the radio communications network;

determining whether the mobile radio terminal is in a given zone; determining whether the at least one cell is reported; updating evidence that the at least one cell is not operating; determining whether the updated evidence exceeds a predetermined threshold; and determining that the at least one cell is not operational if the updated evidence exceeds the predetermined threshold.

In one form, the method further comprises, for each cell reported in the at least one measurement, resetting evidence against the at least one cell not operating.

In one form, the step of resetting evidence against the at least one cell not operating comprises setting an accumulated unreported cell cost to zero and setting a cell count to zero.

In another form, for each cell unreported in the at least one measurement, the step of updating evidence that the at least one cell is not operating comprises computing an unreported cell cost for the at least one cell and adding the computed unreported cell cost to the accumulated unreported cell cost and incrementing the cell count.

In one form, the step of determining whether the updated evidence exceeds the predetermined threshold comprises determining whether the accumulated unreported cell cost is greater than the predetermined threshold.

In another form, the at least one cell is determined to be potentially non-operational if the accumulated unreported cell cost is greater than the predetermined threshold.

According to yet another aspect of the present invention, there is provided a network processor for use in a radio communications network having at least one cell in a zone and at least one mobile radio terminal in the radio communications network, the network processor comprising:

a receiver for receiving at least one measurement, including data relating to at least one cell, from a mobile radio terminal in the radio communications network;

a means for determining whether the mobile radio terminal is in a given zone; determining whether the at least one cell is reported;

a means for updating evidence that the at least one cell is not operating;

a means for determining whether the updated evidence exceeds a predetermined threshold; and

a means for determining that the at least one cell is not operational if the updated evidence exceeds the predetermined threshold.

According to another aspect of the present invention, there is provided a radio communications network comprising a network processor according to the previous aspect.

DRAWINGS

Various aspects of the present invention will now be described with reference to the following Figures in which:

Figure 1 – shows a system architecture of an exemplary radio communications network to which various aspects of the present invention may be applied;

Figure 2 - shows a network arrangement in which a cell identity error arises from a cell coordinate error;

Figure 3 - shows a flowchart of a method of directly detecting an inconsistency;

Figure 4 - shows a flowchart of a method of indirectly detecting an inconsistency by accumulated observations;

Figure 5 - shows a flowchart of a method of detecting the presence of an unknown and incorrectly identified Cell;

Figure 6 - shows a flowchart of a method of detecting non-operational cells;

Figure 7 - shows a flowchart of a method of detecting a non-operational cell becoming operational;

Figure 8 - shows a flowchart of a method of detecting cells with incorrect coordinates;

Figure 9 - shows a flowchart of a method of detecting cells with incorrect coordinates using probability metric;

Figure 10A - illustrates the detection of incorrect cell coordinates for cells A and B heard contemporaneously;

Figure 10B - illustrates the detection of incorrect cell coordinates for cells A and C heard contemporaneously; and

Figure 10C - illustrates the detection of Cells A and C of Figure 10B in another example.

DETAILED DESCRIPTION

Various aspects of the present invention will now be described in detail with reference to one or more embodiments of the invention, examples of which are illustrated in the accompanying drawings. The examples and embodiments are provided by way of explanation only and are not to be taken as limiting to the scope of the invention. Furthermore, features illustrated or described as part of one embodiment may be used with one or more other embodiments to provide a further new combination.

Although many of the examples used to illustrate the embodiments of the present inventions are based on the GSM mobile phone system, the embodiments disclosed herein are readily applied to other mobile phone systems such as UMTS, CDMA-2000, and CDMA IS-95. This is because the parameters being measured and the corresponding cell characteristics have equivalents in each of the mobile phone technologies. For example, a GSM signal strength measurement can be used in the same way as a CDMA-2000 pilot power measurement. As another example, just as the absence of a cell from a GSM Network Measurement Report may indicate a non operational cell, the absence of a particular UMTS Node B from a set of intra frequency measurements may also indicate a non-operational cell.

It will be understood that the present invention will cover these variations and embodiments as well as variations and modifications that would be understood by the person of ordinary skill in the art.

Throughout this specification, the term "mobile" or "mobile phone" is used synonymously with terms such as "cell phones" or "mobile radio terminal", and will be understood to encompass any kind of mobile radio terminal such as a cell phone, Personal Digital Assistant (PDA), lap top or other mobile computer, or pager. Similarly the terms cell is used synonymously with the term cell.

Throughout this specification the term "location system" is used in its most general sense referring to systems that output location estimates with respect to an object or coordinate frame and to systems that output the location estimate as an indication of the proximity to an object or an area. This includes, but is not limited to, zone-based location systems such as that described in PCT/AU2006/000478 entitled "Enhanced Terrestrial Mobile Location".

The term "about" as used herein may be applied top modify any quantitative representation that could be permissively vary without resulting in a change in the basic function to which it is related.

In the following description, when processing is described as being carried out in a mobile terminal, it will be understood that the processing could be carried out in the handset, in the Subscriber Identification Module (SIM) that is inserted in the handset, in an additional processing or smart card inserted into the handset, or in a combination of two or more of these.

In this specification, use of the term network configuration refers to the as deployed network and where relevant also includes the operational state of each component of the network.

It will also be understood that much of the processing that occurs in the implementation of various aspects of the present invention can also be distributed between the handset, one or more network elements or processors within the radio communications network and/or one or more elements outside the radio communications network. It will also be understood that the invention may be applied to any application in which a location estimate for a mobile terminal is required.

Furthermore, the network database referred to in the various aspects of the present invention can be a central repository, a distributed database and/or optionally with full or partial copies distributed to one or more mobile radio terminals.

While the following description uses location and zone based systems to exemplify the operation of the invention, it will be appreciated that the invention is not limited to such applications. The methods described are equally useful for other systems in which a radio network configuration database is maintained as will be understood by one of ordinary skill in the art. One such example is the primary operation of the mobile network in providing voice and data communications where problems with the network configuration degrade the quality of service and/or coverage.

System Architecture

Figure 1 shows an exemplary mobile radio network arrangement in which the various processes may be applied. Shown there is a radio communications network 10 containing a number of Base Stations 11 for communicating with one or more radio mobile terminals 20. Also associated with network 10 is a network processor, such as Location Server 30 and network database 50. Network database 50 may store any kind of data, including a model of the network 10. A system operator 40 may also be present for managing various aspects of the network 10. Network processor 30 may have all the required apparatus for carrying out the various aspects of the present invention, including one or more receivers for receiving data from various network elements such as mobile radio terminals, comparators for comparing data received from the network elements with data in the network database, processors for performing various calculations and computations, and means for outputting the results of these various calculations and computations.

The following sections discuss the different types of network database errors and the impact such errors have can on location estimation and zone-based location systems.

Configuration Vs Database Errors

Any discrepancy between the as configured mobile network and the network database that is supposed to reflect the as configured network does not necessarily mean that it is the network database that needs to be changed. The problem may be that an intended change to the configuration of the network was not carried out or was carried out incorrectly and that it is the configuration that needs to be corrected to ensure the configured network and network database are in synchronisation.

Operational Cell Not In Database

There is a range of scenarios in which a cell can be operational but not in the network database. By 'operational', it is meant that the cell is available for use by a mobile terminal in the vicinity. While the scenarios are different, the effect of the omission on a location system as a practical matter can cause similar operational issues.

A cell may be operating but not necessarily in the network database. The cell site may have been recently commissioned and the database not updated to reflect the addition of the new cells. The network database may have a cell ID error such that the broadcast cell ID does not match that in the database. The cell may be due for decommissioning and was prematurely removed from the network database. The cell may be a temporary cell, commonly referred to as a Cell-On-Wheels (COW), to provide coverage for a short term localized increased in capacity requirements as would occur for large sporting events or festivals.

In a location system, the effect on location estimates of an operational cell being omitted from the network database can degrade performance. As will be described in more detail further below, the cell ID of the serving cell is, in some circumstances, critical for determining the source of the neighbour cell measurements. If the mobile terminal has used as its serving cell a cell that is not in the database, then the neighbour cells may not be able to be identified and the location transaction will not be fulfilled. At the very least any measurements from omitted cells cannot be used as the location of the cell cannot be determined. This results in a drop in the accuracy of the location estimate and could potentially lead to a failed transaction if there remain too few measurements to enable the location estimate to be computed.

For zone-based location systems, the effects of not updating the network database with a new cell can adversely impact the system performance. For a Cell ID based zone system, any subscriber whose zone lies within the range of the new cell could find their service degraded as whenever their mobile terminal camps on the new cell, the mobile may be deemed to be out of the zone even though they may physically be within the zone.

In PCT Patent Application No. PCT/AU2006/000478, the zone computation will consider the measurement of a cell that it does not know as being evidence that the mobile is not in the zone. The overall effect may be to shrink the zone and if the signal strength is sufficiently high the mobile radio terminal may not register ever being in the zone.

Non-Operational Cell In Database

Although a cell is included in a network database it may not necessarily be operating at a given point in time. The cell may be new and not yet made operational. The cell may be temporarily non-operational due to a fault or planned maintenance. The cell's cell identity may be correctly entered and hence from the viewpoint of measurements made the cell identity as listed in the database is never observed and is thus assumed non-operational. The cell may have been decommissioned but not yet removed from the database.

In certain location systems, the presence of a non-operational cell or cells in the database may not degrade location performance. In a system utilising unreported cells in estimating location such as that described in PCT Patent Application No. PCT/2006/000347, the existence of non-operational cells in the database may degrade the accuracy of the system. By referring to a cell as unreported, we mean that it is not reported in a particular set of measurements from a given mobile terminal.

For a Cell ID based zone system, the presence of non-operational cells in the network database may not degrade the performance. However, in a zone-based system such as that described in the previously-mentioned PCT Patent Application No. PCT/AU2006/000478, there may be a degradation in performance. To illustrate, the definition of a zone measured when a dominant cell was operational is likely to feature that cell Should that cell become non-operational it will no longer be reported by a mobile terminal in that zone. This in turn may lead a zone detection system to infer that the mobile is not situated within the zone, unless the database is updated to reflect the non-operational status of that cell.

Cell Identification Parameter Errors

Base stations typically have a unique cell identifier. In the case of GSM the Local Area Code (LAC) and Cell Identifier (CID) uniquely identify a particular cell within a given network. Base stations also have other attributes that can identify the cell to within a subset of the cells in a network. Such attributes include the transmission frequency (ARFCN in GSM, UARFCN in 3G UMTS), the BSIC in GSM and PSC in 3G UMTS. When a network is retuned it is common for the transmission frequency and BSIC/PSC to be changed and as such a retune represents an opportunity for discrepancies to arise between the as configured network and the network database.

Errors in the Cell ID, in certain circumstances, will manifest as an apparent new cell in mobile measurements and a cell that appears to be non-operational in so far that the cell in the database is never reported in any sets of measurements.

When measurements are made of a given cell, the unique cell identifier is usually only obtained for the serving cell. For the neighbour cells the measurements contain one or more of the non-unique identifiers. For example in GSM the BSIC and ARFCN are easily obtained; for 3G UMTS, the PSC and UARFCN are easily obtained. Identification of the cell is achieved by finding that cell with the observed attributes that is the most likely to be heard given the reported serving cell. Techniques for doing this are well known in the art and include finding the cell matching the criteria nearest to the serving cell, and the use of propagation models to determine the matching cell most likely to be heard given the area where the serving cell would be expected to be strongest. Examples of suitable propagation models include the Hata model (see section 2.7 of Mobile Radio Communications 2nd Ed.

Editors Steele and Hanzo, ISBN 047197806X,J. Wiley & Sons Ltd, the 3GPP model (see section 5.1.4 of "Radio Frequency (RF) system scenarios" 3GPP TR25.942) and the T1P1.5 model (see section 3.2 of "Evaluation of Positioning Measurement Systems", T1P1.5/98-110).

Errors in the non-unique cell identifiers may create problems for location systems as the measurements may be associated with the wrong cell or perhaps not associated with a cell at all. Consequently the location estimate or zone detection may be in error.

Figure 2 illustrates this as an example, in which a mobile radio terminal 20 is camped on cell 6692. Mobile radio terminal 20 also hears cell 3451 but since it is not camped, the cell is only identified via the non-unique identifiers: ARFCN=76 and BSIC=55. In the Location Server 30, network measurements sent by the mobile radio terminal 20 are analyzed. One step is to uniquely identify those cells not uniquely identified in the measurements sent by the mobile radio. This is done by searching for a match to the non-unique identifier that is closest to the known (serving) cell. In this example a cell coordinate error results in cell 7587 being selected as the best match. The cell is illustrated as a faded tower to indicate that the cell is not actually the location indicated in the network database. Had the cell not had incorrect coordinates, the correct cell 3451 would have been associated with the measurements.

Incorrect Cell Coordinates

Location estimates are particularly affected by incorrect cell coordinates. In general the error in the location estimate is in proportion to the error in the cell coordinates.

In a Cell ID based location system, the location estimate may be calculated as a weighted average of the locations of the cells heard by the mobile. The location estimate is thus corrupted in proportion to the error in the cell location. In one example, a mobile radio terminal 20 reports ten cells and one of those cells has a coordinate error placing it 1km away from its true location. The effect of the error in this case after the averaging process is to move the location estimate approximately 100m in the direction of the error.

For other types of location systems, the effect of the error can vary significantly depending upon the relative importance of the erroneous cell in the overall position computation. In some cases the erroneous cell is detected and substantially ignored and thus results in a minor loss of accuracy associated with having one less useful measurement. In other cases the affected measurement may play a significant role in constraining the solution; that is it has a disproportionate effect on the location estimate. In such cases, the resulting location error can be large and have a significant impact on the performance of associated location-based applications.

The effect of cell location errors on a zone-based location system, such as that described in PCT/AU2006/000478, may vary. Once the zone has been defined, the location of the cell is typically less critical. During the zone registration phase there are, however, circumstances where cell location errors may affect the performance of a zone-based system. If for instance such a system first computes a location estimate to validate the location of a zone registration request against a nominal location, as described in PCT/AU2006/001479, then cell coordinate errors could lead to the request being rejected as not being consistent with the expected zone location.

A zone based system that incorporates predicted measurements into the zone definition will also typically be affected by cell location errors. For example, in a Cell ID based system zones are defined by the set of cells that can be heard in the zone. These can be assigned by measurement, prediction or a combination of both. Cells that have coordinate errors may be included in a zone where they don't belong, artificially creating a second zone. Conversely a cell with incorrect coordinates may not be included in a given zone definition thus degrading the performance of the zone.

For zones that include signal-strength as part of the definition, the signal level predicted for a cell with incorrect coordinates may be in error. The effect of the error can vary from slightly different zone boundaries to significant zone performance problems such as the mobile being declared out of the zone when actually situated within the area intended to be enclosed by the zone definition.

Other Cell Parameter Errors

There are other cell parameter errors that can affect location estimate and zone performance depending upon the types of measurements used by the system.

Location systems that rely on signal strength can be impacted by errors in antenna azimuth, antenna down-tilt, antenna characteristics such as gain and beamwidth, and effective transmit power levels. A cell that is transmitting at a higher power level than is stated in the network database typically will mean that a location system estimating range to the cell using signal strength will place the mobile terminal closer to the cell than it actually is. Similarly, errors in the parameters associated with the antenna may degrade the location estimate.

Other location systems that do not rely as directly on signal strength may also be degraded by these types of parameter errors. For example timing-based systems may rely on antenna azimuth in order to associate timing measurements with the corresponding cells where such cells were not uniquely identified. Another example is a cell ID based system using the cell centroid. In that system it is necessary to know the antenna characteristics and in particular whether the antenna is directive or omni-directional.

Process

There are various aspects to dealing with network databases with respect to location systems. These are: detection of inconsistencies between the as configured network and the network database; dealing with network inconsistencies once they are detected; and updating the system in response to network configuration changes, corrections to the network database or in response to a detected inconsistency.

The following describes various processes for detection of inconsistencies between the as configured network and the network database. The other two aspects are described in a co-pending patent application entitled "Mobile Service Maintenance Management" filed concurrently herewith.

Detecting Network Inconsistencies

By inconsistency we mean any difference between the actual network configuration and the representation of the network in the network. An inconsistency can include an absence of in the database of a network element that is in the actual network, the presence of a network element in the database that is not in the actual network, and/or a variation in a value of a network parameter in the database from that of the actual database.

In certain embodiments of the present invention, the detection of such inconsistencies is based on analysis of observations of the network signals compared against the network database. Currently, radio network operators typically use dedicated equipment to detect inconsistencies in the radio network. They commonly do so by fitting out vehicles with mobile radio receivers and GPS receivers to map the radio network signals. In one example, taxis are used to provide spatial coverage and are on the move for significant periods of each day. For specific problems the operators may deploy an instrumented test vehicle to survey the area where there is a service problem.

The following describes various processes by which certain types of inconsistencies can be detected. The different processes can be applied in parallel. That is, a given set of observations can be applied to one or more of the processes at the same time and/or in any order. Alternatively, each process may be applied one after the other, or a combination of both.

The observations of the network 10 can come from any receiver that is monitoring the network. This includes for instance the large number of mobile terminals 20 in everyday use. Such mobile radio terminals are continually making measurements of the radio network signals. One aspect of the present invention is to take advantage of existing measurements and use those measurements to detect inconsistencies. This allows the operator to leverage large numbers of temporally and spatially diverse radio measurements available from across the network at minimum additional cost. In the context of a home zone solution, such measurement data is included with zone registrations and location requests. As described herein, the measurement data, if desired, can also be included with other messages from mobiles to the system. This has the advantage of utilizing spare capacity and/or existing communication sessions.

The processes by which inconsistencies are detected can be performed in real-time or through data post-processing. Real-time processing refers to the processing of measurements to detect inconsistencies as soon as practically possible after the measurements become available. For example the measurements would be placed in a queue and the system processes the data in the queue as fast as the system can. Post-processing refers to the accumulation and storage of the measurements for batch processing at a later time. For example the system could process the measurements when it was not processing more urgent tasks

Detection Using A Single Measurement

Certain inconsistencies can be detected from a single measurement which contains data which is inconsistent with that held in a database. Certain inconsistencies can be detected from multiple measurements containing data which in combination is inconsistent with that held in the database.

Depending upon the type of hypothesized inconsistency multiple measurements may be required in order to gain sufficient confidence to act upon the inconsistency.

The process according to one aspect of the present invention, of detecting an inconsistency from a single observation is illustrated in Figure 3. The process begins at step 100. At step 101, measurements of one or more parameters are obtained from the network. In steps 102 and 103, for each measurement, the measurement is compared with its corresponding data in the database 50, or if the measurement is such that a metric should be calculated, a metric is calculated from the corresponding data in the database. Such metrics described herein include but are not limited to calculating the distance between two simultaneously reported cells, computing the zone detection cost associated with a cell. In step 104, a determination is made as to whether the measurement is consistent with its corresponding data in the database. In the case of a calculated metric, this can be compared to a given threshold. If the measurement is consistent with the database or the calculated metric is within the given threshold, the process ends at step 106. If the measurement or the calculated metric are not consistent with the database, then that measurement is marked or flagged as inconsistent. A given set of observations also referred to as measurements, of the network 10, in some forms, will contain data pertaining to one or more cells. For each such cell the data observed is compared against that held in the database or against a metric computed using data from the database. If there is a difference between the observed data and the database, or the computed metric exceeds its associated threshold, then an inconsistency has been detected for that cell. All cells so identified from the set of measurements are then passed on to other processes that take actions to resolve the inconsistencies as are described in the above-mentioned co-pending patent application dealing with management of the detected inconsistencies. Specific uses of the process of detection using a single measurement include the processes illustrated in Figures 5, 7, 8 and 9 as will be described in more detail below with respect to each figure.

Detection Using Multiple Measurements

Inconsistencies can be also detected by accumulating evidence over time or over a series of measurements to support a hypothesis. In particular this is required for inconsistencies for which a single measurement does not provide sufficient confidence to conclude that the inconsistency exists. An example is the detection of a cell being non-operational. Not hearing the cell in any given measurement set does not prove the cell is not operating whereas the converse of presence of a cell in a set of measurements proves that the cell is operating.

Figure 4 illustrates a process flow for accumulating evidence to support a given hypothesis where the hypothesis represents the existence of a type of inconsistency. The process begins at step 200. In step 201, a set of measurements are obtained from the network. In steps 202 and 203, for each cell reported in a set of measurements, the observed parameters are checked to see if the observation contains evidence that denies the hypothesis. As stated above, the presence of a cell in a set of measurements denies for the time being the hypothesis that the cell is non-operational. These steps are illustrated as steps 205 and 206 in Figure 4. In the case where the measurement does not deny the hypothesis, the next step is to use the properties of a zone-based location system to find and accumulate evidence to support the hypothesis. In steps 207 and 208, for each zone, the process determines whether the mobile radio terminal 20 from which the measurements were obtained, is in the given zone. If so, then in steps 209 and 210, for each cell in the zone profile of the given zone, when the mobile radio terminal is in a given zone, there are known expectations of what cells are hearable, the expected signal levels and variation, within that zone. Comparisons between the measurements and the expected measurements from the database enable evidence to be gathered to support or deny the hypothesized inconsistency. As an example, the process could be used to detect a change in the transmit power level by tracking the difference between the expected and observed signal levels for each cell. If the evidence for the hypothesized inconsistency exceeds a configured or predetermined threshold (step 211), the hypothesis is accepted and the cell is flagged as being inconsistent in step 212. In step 213, all cells flagged as being potentially inconsistent are collected for subsequent processing. The process then ends at step 214. A particular example of an indirect detection process using an accumulation of evidence is described in more detail below with reference to detection of non-operational cells and Figure 6.

For particular inconsistencies the step of checking measurements for evidence to deny a hypothesis can be left out. If there are no specific observations that can deny the hypothesis then there is no value in this step. In the case of detecting non-operational cells, the observation of a given cell is evidence that denies the hypothesis. In the case where the hypothesis is that a cell has changed transmit power levels the variability of signal strength observations and relatively small changes made to power levels that a single measurement cannot prove that there has not been a change.

The process of accumulating evidence can also be applied to inconsistencies that are detectable based on a single measurement and hence would be suitable for detection via a direct detection process as described above. In particular, if there is the possibility that any given measurement may be erroneous and provide a false indication of an inconsistency, the evidence accumulation process can be used to make the process more robust. In one example, there is a GSM mobile that is camped on cell 6612 and is also hearing a cell on ARFCN 61 with BSIC 56 which resolves to cell 4459 based on proximity to cell 6612. A data error on 1 bit results in the same cell being reported in a different set of observations as ARFCN 61 with BSIC 57. Within the proximity of cell 6612 this ARFCN/BSIC combination is not found in the database and thus the observation appears as an inconsistency. A threshold could be set such that the inconsistency is only flagged for attention if the same inconsistency is observed one or more times. In certain embodiments the inconsistency detection threshold may be set to between about 1 to about 50 times, or between about 1 to about 10 times, or between about 1 to about 5 times, or between about 1 to about 3 times. In one particular example, there is a system with the threshold set at 3 observations. Continuing the previous example the observation of ARFCN/BSIC 61/57 would need to be observed in 3 separate observations before the inconsistency would be considered to be evidence of a new cell. This is illustrated in Table 1 below.

Table 1

Serving Cell	Unknown ARFCN/BSIC	Count	Inconsistency Reported
6612	61/57	1	No
2186	61/57	2	No
6612	61/57	3	Yes

A further refinement would be to make the criteria include the serving cell. Continuing the above example the ARFCN/BSIC 61/57 would need to be observed with cell 6612 3 times before the inconsistency would be treated as real. This avoids the problem of the same inconsistency from distinct geographical locations being treated as evidence of the same inconsistency. This example is illustrated by expanding upon Table1 whereby the observation with serving cell 2186 is treated as a separate inconsistency with a separate incident count. This is illustrated in Table 2 below.

Table 2

Serving Cell	Unknown ARFCN/BSIC	Count	Inconsistency Reported
6612	61/57	1	No
2186	61/57	1	No
6612	61/57	2	No
6612	61/57	3	Yes

The trade-off is certainty of decision versus time delay in reporting the inconsistency. The more certainty required, for example a higher count threshold, the longer it will take to gather sufficient observations. If a measurement indicates that a previously observed inconsistency is no longer present, the evidence is reset, for example the counter would be set to 0.

Optionally a timer could be associated with an inconsistency such that it must be detected a number of times within a time window before concluding that the inconsistency exists. When an inconsistency is detected the past history of the detections is examined over the configured time window and the number of incidents counted.. If the count equals or exceeds the threshold, then the conclusion is that the inconsistency exists. This approach has the advantage of inconsistencies caused by data errors which are expected to be rare events from accumulating over a long period and eventually causing an inconsistency to be falsely concluded to exist reported. The time window can be configurable. Time windows could vary over a number of ranges of time, for example, from about 0 to about 24 hours, or from about 0 to about 1 hour, or from about 0 to about 15 minutes, or from about 0 to about 6 hours, or from about 0 to about 48 hours, or from about 10 seconds to about 3600 seconds, or from about 10 seconds to about 300 seconds.

Table 3 illustrates the method by extending the example from table 1. The time, in the example measured in seconds from an arbitrary epoch, at which an inconsistency is observed is noted. The number of occurrences of the same inconsistency within the configured time window, in this example 300 seconds, is counted each time the inconsistency is detected. If the threshold is reached within the time window, the inconsistency is treated as real. In the example the threshold is 3 and this threshold is reached within a 300 second window at time 23872 seconds. It should be clear to one of ordinary skill in the art that the inconsistency criteria can be extended to include the serving cell as described above and illustrated in Table 2.

Table 3

Serving Cell	Unknown ARFCN/BSIC	Time (seconds)	Count over 300 seconds	Inconsistency Reported
6612	61/57	12876	1	No
2186	61/57	23611	1	No
6612	61/57	23732	2	No
6612	61/57	23872	3	Yes

In certain embodiments, the window may be defined in terms of the number of opportunities presented to the system in which the inconsistency may be detected rather than in terms of elapsed time. An example of an opportunity to observe an inconsistency is the receipt of a message from a mobile by the server where the message contains radio measurements as described herein. In some instances, the system may be configured to require the number of detections to exceed a threshold and for that number of detections to occur within a number of opportunities.

The detections threshold may be set to between about 1 and about 5, between about 1 and about 20, between about 1 and about 100, between about 3 and about 10, between about 5 and about 50, between about 20 and about 100, or between about 50 and about 1000. The opportunities threshold may be set to between about 100 and about 10,000,000, between about 200 and about 1000, between about 500 and about 2000, between about 1000 and about 5000, between about 2000 and about 10,000, between about 5000 and about 20,000, between about 10,000 and about 50,000, between about 20,000 and about 100,000, between about 50,000 and about 200,000, between about 100,000 and about 500,000, between about 200,000 and about 1,000,000, between about 500,000 and about 2,000,000, between about 1,000,000 and about 5,000,000, or between about 2,000,000 and about 10,000,000. As an example, consider a network with 2000 cells and on average each message containing radio measurements contains 6 cells. On average a cell indicating an inconsistency will only be present once every 333 messages. To be reasonable confident that a reported inconsistency is valid and to provide a reasonable likelihood that the inconsistency will be detected the criteria could be specified as 3 detections within 2000 opportunities.

Detecting Unknown and Incorrectly Identified Cells

Figure 5 illustrates a process flow for detecting the presence of a cell that is not in the database or for which one or more cell identification parameters does not match that in the database.

Starting at step 300, the process takes one or more measurements at step 301 of the network signals and compares for each measurement the cell identity information against that in the database as shown in steps 302, 303 and 304. Using one or more of the techniques described elsewhere in this specification the cell identifiers included in the measurements are checked.

If the result of this processing indicates that the cell identifiers are not in the network database, the cell is flagged as unknown in step 307. If the result of this processing indicates that the cell identifiers are known, then a check is made in step 305 to see if the known cell identifiers are consistent with the network database. If not, then the cell is flagged as inconsistent in step 306. In step 308, all of the flagged cells are gathered together for subsequent processing according to one or more methods of the co-pending patent application referred to above relating to management of detected inconsistencies. This process ends in step 309.

The following provides detailed examples of carrying out various aspects of the above method.

Detecting Unknown Cell Based on Unique Identifier

The observation of a cell ID that is not present in the network database represents an inconsistency between the as configured network and the network database. The unknown cell ID could represent a cell recently made operational but not in the database, a cell prematurely removed from the database, or a cell assigned the wrong ID in the network or in the database.

One example is a GSM system in which a new base station site is installed. At this site there are three cells with parameters as shown in Table 4 below. The data associated with these new cells has not been updated into the network database. A set of measurements is shown in Table 5 below. The system will detect the Cell ID 25071 as an unknown cell as the Cell ID will not be present in the database.

Table 4

CellID	ARFCN	BSIC
25070	95	38
25071	81	59
25072	67	46

Table 5

CellID	ARFCN	BSIC	RxLevMean(dBm)
25071	Unknown	Unknown	-83.0
Unknown	71	61	-92
Unknown	67	46	-99
Unknown	69	43	-103
Unknown	73	34	-103

Based on the example for GSM it will be clear to those of ordinary skill in the art how to apply the method to other radio access technologies such as UMTS, CDMA-2000, and CDMA IS-95.

Detecting Unknown Cell Based on Non-Unique Identifier

Base stations that have only been identified by partial identifiers are associated with cells by searching for a match to the partial identity within the vicinity of the serving cell. Failure to find a match for the partial identity indicates an inconsistency between the as configured network and the network database. The failure, however, cannot be attributed to a specific cause. Potential causes include, but are not limited to, a new cell in the network; premature removal of a cell from the database; incorrect partial identifier information in the database; incorrect coordinates for the serving cell, and incorrect coordinates for the neighbour cell.

One example is a GSM system in which a new base station site is installed. At this site there are three cells with parameters as given in Table 1 above. The data associated with these new cells has not been updated in the network database. A set of measurements is shown in Table 6. The system will attempt to identify the unique identity of the neighbour cells that are partially identified by Cell ID and BSIC. A search within the vicinity of Cell 26078 fails to find a match for the ARFCN/BSIC pair of 81/59. The failure to match the identity of this measurement indicates the presence of an unknown cell.

Table 6

CellID	**ARFCN**	**BSIC**	**RxLevMean(dBm)**
26078	Unknown	Unknown	-87.0

CellID	ARFCN	BSIC	RxLevMean(dBm)
Unknown	71	61	-92
Unknown	81	59	-99
Unknown	69	43	-103
Unknown	73	34	-103

Where a system or network element, for example a mobile radio terminal, contains a partial copy of the network database, inconsistencies can be detected in some circumstances where the observed identifiers contradict the data that the mobile contains. When partial identifiers are reported in conjunction with a unique identifier, the partial identifiers can be cross-referenced against the unique identifier. For example, if the mobile radio terminal contains a reference to GSM Cell ID 24141 with ARFCN 59 and BSIC 51 but observes Cell ID 24141 on ARFCN 32 and BSIC 27 then an inconsistency has been detected.

Based on the example for GSM given above, it will be clear to those of ordinary skill in the art how to apply the method to other radio access technologies such as UMTS, using UARFCN and PSC and CDMA IS-95 using the channel number / PN offset.

Detecting Unknown Cells via Zone Detection

A mobile radio terminal will not necessarily store the entire network database and hence may not be able to identify all of the inconsistencies discussed above. One aspect of this invention is a method for a mobile radio terminal to alert the server 30 to the possibility of there being an inconsistency between the as configured network and the network database. In a zone-based location system the mobile contains one or more zone profiles and each such profile contains a subset of the network database. The zone detection process evaluates the difference between current measurements and that expected to be seen in a given zone as defined by the profile for that zone. Each measurement makes a contribution to the decision as to whether the mobile is in a given zone or not. If a single measurement is responsible for a significant portion of the decision metric, then the computation is repeated with that cell removed. If as a result the mobile radio terminal is deemed to be within the zone, the cell associated with the measurement is flagged as representing an inconsistency. An indicative portion for a measurement's influence to be deemed significant is 40% of the decision metric's value. The proportion of the cost deemed significant could be in the range of about 10% to about 80%, about 10% to about 30%, about 15% to about 40%, about 20% to about 50%, about 30% to about 60%, about 40% to about 80%. The technique is particularly useful for detecting newly commissioned cells and errors in the configuration of the network that have arisen during a network retune.

Table 7

CellID	ARFCN	BSIC	RxLevMean	Sigma
25068	95	38	-60.0	9
54763	81	59	-88.3	9
18322	67	46	-92.1	9
892	71	61	-98.7	9
18581	73	34	-103	9

A GSM radio zone profile is given in Table 7. In this example, a new set of measurements is available as illustrated in Table 8 below and these will be used to evaluate the zone status against the profile from Table 7. The ARFCN and BSIC are not available for the serving cell because they are not reported in the Network Measurement Report (NMR) data.

Table 8

CellID	ARFCN	BSIC	RxLev (dBm)
49844	Unknown	Unknown	-83
Unknown	95	38	-89
Unknown	81	59	-90
Unknown	71	61	-92
Unknown	67	46	-99
Unknown	69	43	-102

The total cost is calculated as described in PCT Patent Application No. PCT/AU2006/000478 by summing the costs corresponding to the matched, unmatched and unreported cells. The calculated values for the matched cell costs are shown in Table 9, represented to 2 decimal places.

CellID	ARFCN	BSIC	Profile RxLev	Measured RxLev	Cost
25068	95	38	-85.0	-89	0.20
54763	81	59	-91.3	-90	0.02
892	71	61	-98.7	-92	0.55
18322	67	46	-92.1	-99	0.59

The calculated value for the single unreported cost is shown in Table 10. In this example the unreported cell is not included in the cost because it would not be expected to be heard given the levels that the other signals were reported at.

Table 10

CellID	ARFCN	BSIC	Profile RxLev	Threshold	Cost

CellID	ARFCN	BSIC	Profile RxLev	Threshold	Cost
18581	73	34	-103	-102	0.00

The calculated value for the unmatched costs is shown in Table 11.

CellID	ARFCN	BSIC	Measured RxLev	Threshold	Cost
49844	Unknown	Unknown	-83	-103	4.94
Unknown	69	43	-101	-103	0.05

The total cost is 6.35. The cost of the cell 49844 represents 78% of the cost. This exceeds the indicative threshold of 40% so the test is performed. The cell is not included in the zone detection test. The total cost is now 1.41. The threshold at the 80% probability level, derived from a chi-squared distribution with 5 degrees of freedom, is 2.34. The cost is less than this threshold and thus excluding the cell with the large cost would result in the mobile being declared in the zone. Thus the cell 49844 is declared to be a new cell. The same process can be used to identify the presence of a new cell that was only identified by non-unique identifiers (ARFCN + BSIC). In this instance the presence of the unknown cell would be detected but its unique identity would not be known.

A mobile radio terminal can only measure cells that are in its vicinity. Base station coordinate errors may be detected by identifying measurement sets that are incongruous. Various metrics can be used to evaluate the likelihood that a cell's coordinates in the database are incorrect or that a given set of measurements contains one or more cells with suspect coordinates.

Detecting Non-Operational Cells

In any given measurement set, the existence of a cell constitutes proof that the cell is operating. The converse is not true; the absence of a given cell in a given set of measurements does not necessarily constitute proof that the cell is not currently operating. According to one aspect of the present invention, a process to detect cells suspected of not operating is to accumulate evidence from a series of one or more sets of measurements until such time as a decision can be made about the operational state for a given cell.

Figure 6 illustrates a process flow for detecting cells that are in the network database 50 but which appear to be non-operational. The process begins at step 400 to obtain measurements from the network at step 401. For each cell that is observed in a measurement set, the cell is deemed to be operating and hence the evidence that it is not operational is reset to 0 at steps 402, 403 and 404 by setting Cell Cost = 0 and Cell Count = 0.

If the mobile radio terminal 20 is in a zone, then there exists the opportunity to update the evidence that cells that have not been reported may be non-operational. From step 405 the following steps are taken for each zone being considered. A zone is a region within the mobile radio communications network 10 that may be defined by various means, including those described in PCT/AU2006/000478 entitled "Enhanced Terrestrial Mobile Location". In step 406, a determination is made as to whether the mobile radio terminal 20 is in the zone. Again, various methods may be used to determine whether the mobile radio terminal is in or out of the zone, including those described in detail in this same incorporated reference. In steps 407 and 408, it is determined for each cell in the zone profile, whether the cell was reported. If not, the evidence that the cell is not operating is updated in step 409 by computing the unreported cell cost and adding this to the accumulated cell cost and incrementing the cell count. If the cell is determined to be reported, the process ends at step 413.

In step 410, the collected evidence is compared with a threshold. In this case, if the accumulated unreported cell cost is greater than the threshold for the cell count (i.e. the threshold is exceeded), the cell is flagged as potentially non-operational in step 411. In step 412, al cells that have been flagged as potentially non-operational are collected for further processing

The following sections provide detailed examples for detecting non-operational cells

Detecting Non-Operational Cells at Server Based on Unreported Cost.

In one aspect of the present invention, a means and method is provided for detecting that a particular network cell is out of service. This is done using the measurements observed by one or more mobile radio terminals. The detection process uses a metric reflecting the expectation of having not observed a cell given the other cells that were observed. With each set of measurements the metric is accumulated for each cell. A cell is flagged as non-operational when the accumulated metric is evaluated and deemed to contain insufficient evidence that the cell is currently operating. For each cell present in a set of measurements the metric accumulator is reset.

Different metrics can be used to determine whether a cell is operational or not. For a given measurement set the probability of not reporting a given cell given the observed signal measurements and assuming that the cell is operating can be calculated. These probabilities can then be accumulated for a given cell over a series of measurements by multiplying the probabilities. If the accumulated probability crosses a threshold, for example 0.005, the cell is flagged as non-operational. When a cell is present in a measurement set, the accumulated probability is reset to 1.

Another metric is to compute a statistic such as the chi-squared statistic, for each cell and accumulating the statistic by adding the values over a series of measurements. When the accumulated statistic exceeds a defined threshold the cell is deemed to be non-operational. If the cell is present in a given measurement set the statistic is reset to 0.

Yet another metric is to accumulate the time since a cell was last reported. A cell that has not been included in a measurement set for longer than the configured interval is flagged as non-operational.

Yet another metric is to accumulate the number of measurement sets that have been processed since a cell was last reported. A cell is flagged as non-operational if it has not been reported within the most recent n messages. Such a metric avoids the false alarms that time-based metrics can generate during quiet periods such as the early morning.

In one embodiment for a zone-based location system such as PCT/AU2006/000478, the process at the server operates on all cells in the network which feature in one or more zone profiles. For each of these cells the unreported cost is accumulated each time a new set of measurements yields a large unreported cost but the remaining profile elements yield a good match for the measurements. The general process is to examine each cell that relative to a given zone profile is not reported in a given set of measurements. If the cost of a given unreported cell is deemed significant and when this cell is ignored the remaining measurements indicate that the mobile is in the zone, then the cell is deemed potentially non-operational and the evidence to support this is accumulated.

It is common for a site to be non-operational and consequently all cells located at that site would be non-operational. The reasons for this are due to the resources shared by all cells at a site; in particular power and data. It should be clear to those of ordinary skill in the art that the algorithm described can also be applied on a site basis. In this mode of operation the unreported cost is accumulated on a per site basis.

For each of these cells the unreported cost is accumulated each time a new set of measurements yields a large unreported cost but the remaining profile elements yield a good match for the measurements. In physical term, such an observation indicates that the mobile radio terminal is located in a place where the measurements are consistent with the profile but this particular cell is not reported. Each time a cell is reported however, the accumulated cost is reset to zero since the cell is clearly not in an outage state.

The following description illustrates a scenario based in a GSM network in which a measurement yields a large unreported cost, such that a cell outage may be indicated.

This example uses the profile defining a zone as shown in Table 12.

Table 12

CellID	ARFCN	BSIC	RxLevMean	Sigma
25068	95	38	-60.0	9
54763	81	59	-88.3	9
18322	67	46	-92.1	9
892	71	61	-98.7	9
18581	73	34	-103	9

In this example, a new set of measurements is available as illustrated in Table 13 below. The ARFCN and BSIC are not available for the serving cell because they are not reported in the NMR data.

Table 13

CellID	ARFCN	BSIC	RxLevMean(dBm)
54763	Unknown	Unknown	-83.0
Unknown	71	61	-92
Unknown	67	46	-99
Unknown	69	43	-103
Unknown	73	34	-103

The total cost is calculated as described in previously-incorporated PCT Patent Application No. PCT/AU2006/000478 by summing the costs corresponding to the matched, unmatched and unreported cells. The calculated values for the matched cell costs are shown in Table 14, represented to 2 decimal places.

Table 14

CellID	ARFCN	BSIC	Profile RxLev	Measured RxLev	Cost
54763	81	59	-88.3	-83	0.17
892	71	61	-92.1	-92	0.00
18322	67	46	-98.7	-99	0.00
18581	73	34	-103	-103	0.00

The calculated value for the single unmatched cost is shown in Table 15.

Table 15

CellID	ARFCN	BSIC	Measured RxLev	Threshold	Cost
Unknown	69	43	-103.3	-105	0.02

In this example, since the measurement was not fully populated, using the methods described in previously-incorporated PCT/AU2006/000347 (referred to above and herein incorporated by reference in its entirety), an unreported threshold value of -105 is used. The calculated value for the unreported cell cost is shown in Table 16:

Table 16

CellID	ARFCN	BSIC	Profile RxLev	Threshold	Cost
25068	95	38	-60.0	-105	15.07

A suitable threshold at which an unreported cost is considered significant enough to be accumulated for outage detection is about 2.0 for example. However, any other suitable thresholds could be used, such as between 0 and 0.5, 0.2 and 1.5, 1.0 and 3.0 or between 1.5 and 5.0 or between 2.0 and 6.0 for example.

Having determined that there is an unreported cell for which the threshold has been exceeded, there needs to be a determination that the cell was expected to be heard before the cost can be accumulated as evidence that the cell is not operating. Using the process described in previously-incorporated reference PCT/AU2006/000478, the zone status is calculated but with the unreported cell in question not considered in the computation. The threshold which the other costs must not exceed in order for the unreported cost to be accumulated is defined in terms of the chi-squared threshold in the same way as for the zone status, taking into account the number of constraints (not counting the unreported constraints). In the present example, the total number of other constraints is 5. The chi-Sq threshold value is obtained as the 90th percentile from the ChiSq cumulative density function with 5degrees of freedom. Using a numerical approximation to this function, rounded to 1 decimal place, the value is 9.2. The total of matched and unmatched costs is 0.19 which is less than the chi-sq value of 9.2.

In the example above, the mobile is determined to be in the zone if the unreported cell is ignored. This combined with an unreported cost that exceeds the threshold means that the unreported cost is accumulated towards the cell being declared non-operational. The cost is accumulated by adding the current unreported cost to the accumulated cost. Once the accumulated cost exceeds a threshold, the cell is declared non-operational. Any time the cell is observed, the accumulated cost is reset to 0 since the cell is clearly operational. A suitable threshold for the total accumulated unreported cost threshold before declaring an outage to be indicated is about 20 for example. However, any other suitable threshold may be used, including between 10 and 15 or between 15 and 30 or between 20 and 40 for example.

Detecting Non-Operational Cells at Mobile Terminal

A limited scale version of the process illustrated above may also be operated at each mobile terminal. In this case however the outage analysis at a mobile terminal focuses only on the cells that feature in a zone profile being monitored at that terminal. In this case a historical unreported cost is maintained for cells included in such a zone profile. In the event that for a particular profile, all but a few elements are matched and the remaining elements attract a large unreported cost, these unreported costs may be accumulated.

When the accumulated unreported cost for one or more cells reaches the threshold, a message may be sent to the server bearing the current radio measurements. The purpose is to trigger the server side cell outage detection processing using the current measurements and potentially trigger the disabling of that cell.

This mobile radio terminal focused aspect may be useful in some cases because a mobile radio terminal may return to a zone after a cell has been taken out of service. The lack of measurements for that cell may prevent the mobile from ever detecting itself as home and therefore prevent any radio measurements being sent to the server. As a result, the server would never have data from which to detect the outage and the zone service will be interrupted. By performing this limited outage analysis at the mobile radio terminal, it is possible to detect such cases and activate the outage processing in the server.

Detecting Non-Operational Cells In Server

The elapsed time since a cell was last reported can be used to establish whether a cell is believed to be operational or not. In one aspect of the invention, the time at which a cell was last reported is associated with each cell enabling the elapsed time since last seen to be calculated for every cell at any given epoch. Any cell for which the elapsed time since last report exceeds a specified threshold is deemed to be non-operational. The threshold is optionally configurable. The threshold chosen represents a trade-off between responsiveness and false alarms. The larger the time before reporting a cell as non-operational, the less likely it is that the report is a false alarm. Indicative values for the threshold are between 1 minute and 5 minutes, between 2 minutes and 20 minutes, between 5 minutes and 60 minutes, between 15 minutes and 120 minutes.

The threshold can optionally change based on the time of day to reflect that the expected time between reports will be longer when there is less people movement such as early in the morning. If the rate of observations varies significantly throughout the day or by day-of week, a more appropriate threshold is one based on the number of elapsed transactions since the last observation rather than the elapsed time. As each transaction arrives it is assigned an value that is incremented with each transaction. Each cell is then assigned the value of the most recent transaction in which it was observed. Once the number of transactions since a given cell was last observed is exceeded it is deemed non-operational. The threshold is again a trade-off between responsiveness to a cell becoming non-operational and false alarms. Consider a network with 3000 cells and on average 6 cells are reported per set of observations. In such a network a minimum 500 sets of observations are required for every cell to have the possibility of being reported once. Taking into account the random nature of which cells are reported, a reasonable value is 3 times the minimum setting the threshold at 1500.

In another aspect of the invention, elapsed time is measured relative to the rate of transactions coming into the location server. The location server maintains a transaction counter. Associated with each cell is the transaction counter value associated with the transaction in which the cell was last detected. The elapsed time since a cell was last reported is measured as the difference between the current transaction counter value and that stored for the cell. A given cell is deemed non-operational if the number of transactions since last update exceeds a specified threshold. Optionally the threshold is configurable. For example in a network with 2000 base stations and a GSM network in which mobile reports at most 7 cells at any time, it would take approximately 300 messages to see each cell reported once ignoring the randomness of such reports. The threshold could be set at 3000 to allow for the random distribution of which cells were reported. Using the elapsed transaction count metric has the advantage of adapting to the rate at which transactions are being gathered and hence automatically handles the periods where the actual elapsed time is expected to be larger due to fewer incoming transactions.

In another aspect of this invention, the server can optionally seek to obtain further evidence that a cell is non-operational by requesting certain mobiles send measurements to the server. If a given cell is suspected of having failed, the server can search zone profile definitions to find zones which include the suspected cell. Optionally the server could prioritise the list of zones based on the signal strength order of the zones. Zones where the suspect cell is expected to be highest are given preference where the suspect cell is second highest and so on. From this zone list the server seeks mobile radio terminals that are in the zone. Such mobile radio terminals, optionally based on zone preference, are then requested to send a set of measurements, for example by forcing a status update. The number of mobiles so targeted is configurable.

Detecting Non-Operational Cell Becoming Operational

Figure 7 illustrates a process flow for detecting cells that have been flagged as non-operational (for example, by one or more of the previously-described methods), but have been re-activated. Whenever a cell that has been flagged as non-operational is observed in a measurement set the cell is flagged as being operational. The process starts from step 500 to collect measurements from the network at step 501. For each reported cell, the operational status is checked at steps 502 and 503. If in step 504, the cell has been flagged as non-operational (for example by the previously-described method), the cell is then flagged for reporting in step 505. If the cell has not been flagged as non-operational, no further action is taken.

In step 506, the cells flagged in step 505 are gathered together for potential reinstatement as operational. The process then ends in step 507.

The following provides a detailed example of performing the above described method.

The server can detect the reappearance of a non-operational cell using the same algorithms used to detect non-operational cells. When monitoring the network for non-operational cells the presence of a cell deemed non-operational in a set of measurements indicates that the cell is operating again.

As an example consider a set of measurements made on a GSM network as shown in Table 17. Using the network database and proximity to the cell 25652 the cell with ARFCN 68 and BSIC 51 is resolved to be cell ID 54312. This cell is flagged in the server database as non-operational (Table 18). The detection of cell 54312 infers that it is again operational and consequently the operational status is changed.

Table 17

CellID	ARFCN	BSIC	RxLevMean(dBm)
25652	Unknown	Unknown	-87.0
Unknown	56	66	-94
Unknown	61	54	-95
Unknown	68	51	-95
Unknown	29	46	-102

Table 18

CellID	ARFCN	BSIC	Operational
25652	31	39	Yes
38821	56	66	Yes
49731	61	54	Yes
54312	68	51	No
54311	29	46	Yes

Detecting Cells With Incorrect Coordinate

Figure 8 illustrates a process flow for detecting cells that have incorrect coordinates. From step 600, the process obtains the network measurements in step 601. In step 602, the process determines the distance between all pairs of cells that have been measured contemporaneously based on the coordinates of the cells in the network database. For each cell a metric relating to the relative proximity of the cells is computed and if the metric exceeds the criteria as determined in steps 603 and 604, then the cell is flagged in step 605 as potentially having incorrect coordinates.

In step 606, the flagged cells are collected for subsequent further processing, and the process ends at step 607.

The following provides detailed examples of performing various aspects of the above method for detecting a cell with incorrect coordinates.

A mobile radio terminal can only measure cells that are in its vicinity. Base station coordinate errors can be detected by identifying measurement sets that are incongruous. Various metrics can be used to evaluate the likelihood that a cell is in the incorrect location or that a given set of measurements contains one or more cells with suspect coordinates.

Detection Using Distance Metric

The cells measured by a mobile radio terminal typically come from the same geographic area. As such, the average or median distance from each cell in a measurement set to the other cells in the set should be comparable. A cell having a distance metric much higher than the others may be an indication of a cell with a coordinate error. One such metric that may be used is the median distance.

In one embodiment, for each cell the median distance to the nearest n cell sites is computed. As an example, n could be 8, although any value in the range of about 2 to about 20, about 2 to about 5, about 3 to about 8, about 4 to about 12, or about 2 to about 8, could be used. Any contemporaneously reported pair of cells that is more than m times the average of the two median distances apart is deemed to indicate a cell potentially in the incorrect location. As an example m could be 2 although any value in the range of about 1 to about 20, about 1 to about 3, about 2 to about 5, about 3 to about 8, or about 5 to about 20 could be used.

Table 19 shows a section of a network database with the median distance from each base station to the nearest 8 base station sites using a metric for the separation of base stations in the vicinity of each base station. A set of contemporaneous measurements reports cell IDs 26078 and 4415. The distance between these cells is 2002m. This distance is under the median distance for both cells so the measurement provides no indication of an incorrectly located base station. A different set of contemporaneous measurements reports cell IDs 26078 and 5617. The distance between these cells is 18006m. This metric is 2 times the larger of the median inter-site distances involved which is 11202m. Hence the measurement indicates that a cell may have incorrect coordinates.

Table 19

CellID	Median Distance to Nearest 8 Sites (m)	Easting	Northing
26078	5601	6495885	2662920
5617	4321	6478631	2673922
8173	7840	6482814	2672664
4415	3400	6493345	2663641

Detection Using Signal Detection Likelihood

Where a set of measurements contains more than one unique cell identifier, cell coordinate problems can be detected by evaluating a metric that measures the likelihood that all such identified cells could be contemporaneously heard at the reported signal strengths at a given location in the network. By evaluating this metric over the network coverage area the maximum likelihood can be found. The maximum likelihood is compared against a threshold. If the likelihood is below a threshold, then the set of observations indicates that there is a potential problem with the location of one or more cells.

Figure 9 illustrates steps of a method for determining the detection of a cell in the wrong location using a probability metric. The process begins at step 700, to obtain network measurements at step 701. In step 702, a probability that each reported cell is in the correct location is computed (described in more detail below). For each cell (step 703), a comparison is made between the computed probability and a threshold in step 704. If the probability is less than the threshold, the cell is flagged as being potentially in the wrong location in step 705. In step 706, the flagged cells are gathered together for subsequent processing. The process then ends in step 707.

For any given location x, the expected signal strength at x for each cell can be estimated using techniques well known in the art such as the Hata model (see section 2.7 of Mobile Radio Communications). The difference between the measured signal strength and the estimated signal strength is affected by the difference between x and the true location of the mobile radio terminal, the accuracy of the cell location, the accuracy of the model, and the variability of signal strength measurements. Using optimization techniques well known in the art the maximum likelihood can be estimated. The point x at which this occurs is the maximum likelihood estimate of the mobile radio terminal's location. This location is not required in this instance as it is the maximum likelihood value itself that is the quantity of interest. It is well known in the art that if only two cells are identified, the location estimate is ambiguous; there will be two equally likely locations at which the cost is minimised. This is not relevant in the problem being addressed in this example - it is simply an artifact of the process. To which location the algorithm converges does not matter as it is the minimized cost and not the location that is of interest.

For a signal strength model using Gaussian errors, it is well known in the art that the maximum likelihood calculation is equivalent to finding the location x that minimizes the following equation:

$$\chi^2 = \sum_i \frac{(S_i - f_i(x))^2}{\sigma_i^2}$$

Where

S_i is the measured signal strength for cell i, $f_i(x)$ is the estimated signal strength at x for cell i, and σ_i^2 is the variance of the signal strength for cell i due to the type of radio environment. The measurements S_i are contemporaneous. χ^2 is the cost that is minimized and is a chi-squared statistic for which the number of degrees-of-freedom is the number of cells heard. The χ^2 statistic is converted to a probability and it is this probability that is compared to the threshold. If the threshold is exceeded, then the scenario indicates that one or more cells involved potentially have a coordinate error. The threshold is configurable and is a trade-off between reliably detecting coordinate errors and the number of false alarms. Since the coordinate error is static, the detection threshold can be set reasonably large to reduce the number of false alarms. Such a threshold will simply increase the expected time it will take for a given error to be detected. The threshold may be set to any desired value. In one example, the threshold could be in the range about 95% to about 99.99%, and including about 96%, 97%, 98%, 99% or 99.5% or about 99.99%. The threshold may even be set lower than 95%, for example in the range from about 70% - about 90% or about 80% - about 95%. Having determined that one or more cells are potentially in the wrong location, the next step is to determine which cells to flag for further action. The simplest choice is the default case where all cells involved are flagged as potentially being in the wrong location and the problem of identifying which, is left for an external system, for example a network operations team. Another choice is based upon the examination of the cost that each cell contributes to the total and if it exceeds a threshold, it is flagged as being potentially in the wrong location. The ability of this approach to detect the cell at fault improves with the number of cells included in the computation. As described above, the cost will be a χ^2 statistic but with one degree of freedom. Again the statistic is converted to a probability and compared against a threshold probability, for example, 98%, or any other ranges as described above. As described elsewhere in this specification, evidence can be accumulated over multiple measurement sets and the decision based upon the accumulated evidence. In this scenario, the χ^2 cost contribution for each cell can be accumulated and compared against a probability threshold.

The method used to detect cells in the wrong location using measured signal strengths can also be applied to timing observations. Given the description of the method above it should be clear how to apply the method to timing measurements.

Table 20 shows part of a network database. Table 21 shows an excerpt of a set of measurements that illustrate cells A and B heard contemporaneously, as shown in Figure 10A. The signal levels have a range correspondence, using the Hata model, of 2415m and 4930m respectively for cells A and B. Circular arcs centred on A and B using these ranges intersect at two distinct points P and P′. At either of these two points the cost function evaluates to 0 which is clearly less than any chosen chi-squared threshold. As such, there is no evidence that either cell has a significant coordinate error.

Table 22 shows an excerpt of a set of measurements that illustrate cells A and C heard contemporaneously, as illustrated in Figure 10B. Note however that the true location of the cell is distinctly different to that in the database which the following analysis will reveal. The signal levels have a range correspondence, using the Hata model, of 2415m and 203m respectively for cells A and C. Circular arcs centred on the coordinates of A and C, as defined in the database using these ranges, do not intersect. Using numerical optimization techniques well known in the art, the point at which the cost is minimized is determined and shown as point X in Figure 10B. For a standard deviation of 8dB, appropriate for a suburban radio environment, the minimum cost is found to be 19.02. The chi-squared threshold for 99.9% is 14.1. Thus the cost exceeds the threshold and the observed signal strength is deemed to have arisen from variations due to noise. Thus either both of the cells are deemed to potentially have a coordinate error. Further measurement sets involving A or C would indicate which was the more likely to be in error. Note that had the coordinates for C been correct in the database, the circular loci would not intersect, at the optimal estimate X′ as shown in Figure 10C. The resulting minimized cost would be 0.28, well below the threshold.

It should be clear to those of ordinary skill in the art that the technique can be extended to situations where multiple signals are uniquely identified. The more signals so available makes the technique better able to distinguish which cell actually has the wrong coordinates.

Table 20

CellID	Easting	Northing
A (in DB)	455161	6654541
B (in DB)	457832	6654541
C (in DB)	478751	6651368
C (True)	455511	6651368

Table 21

CellID	RxLevMean(dBm)
A	-84.4
B	-96.7

Table 22

CellID	RxLevMean(dBm)
A	-84.4

CellID	RxLevMean(dBm)
C	-46.5

Detection Based on Zone Location

Described in PCT/AU2006/001479, is the association of a nominal location to a zone. Similarly when a zone is measured, the measurement data can also be used to estimate the location of a zone. Either of these locations can be used to assist the detection of a cell with incorrect coordinates.

The methods described earlier detect the presence of potential cell coordinate errors with no prior information pertaining to the location where the measurements were made. Using the zone location, the evaluation metrics can be further refined. If measurements are known to be made within the vicinity of a zone with a known location, for example the measurements were triggered via a zone transition, then the measurements can be evaluated assuming they came from the location of that zone.

Distance Metric

With regard to the distance metric, the distance from the zone location to each cell can be computed. This distance is then compared to a multiple of the inter-cell distance metric for that cell. The comparison can explicitly include an allowance for the accuracy of the zone location or implicitly include such an allowance via a larger multiple of the distance metric. In one example, there is a cell with ID 38761 for which the inter-cell median distance is 1540m. If the validation multiplier is set to 2.5, that is, in this network, a cell is not expected to be hearable at a distance from the cell of 2.5 times the inter-cell distance which in this example is 3850m. If a cell is reported from in or near a zone that is 10561m away from the cell, this distance exceeds the maximum expected range for the cell and thus the cell is flagged as potentially having incorrect coordinates.

Signal Detection

With regard to the signal detection likelihood metric, the computation is constrained to be evaluated at the known location. An allowance made for any uncertainty in the location of the zone can be made by increasing the standard deviation of the signal level. Using a signal propagation model an appropriate allowance can be computed. If for example the zone location has an uncertainty of 500m 2DRMS, the T1P1.5 propagation model in a suburban environment at a range of 3000m from the base station indicates that an appropriate allowance would be to increase the signal strength by 2dB.

Reusing the example in Table 10, Table 11 and Table 12, the use of the zone location can be illustrated. The nominal location of the zone is coordinates (455411, 6651528). There is now no need to minimize the cost function as there is a reliable estimate of the location of the mobile. At the estimated location the estimated signal strengths are -87.8dBm, -91.6dBm, and -119.1dBm for cells A, B, and C respectively.

In the scenario where cells A and B are heard contemporaneously and with the solution constrained to the nominal location of the zone the cost is 0.54. This is well below the 99.9% threshold and the test results do not indicate any detectable problem with cell coordinates.

In the scenario where A and C are heard contemporaneously and with the solution constrained to the nominal location of the zone the cost is 82.5 which is significantly higher than the 99.9% chi-squared threshold as chosen in the previous example. Thus the measurements indicate that there is a potential problem with the coordinates of one or both base stations. Had cell C had the correct coordinates, the cost would have been 0.2 and well below the threshold.

Signal Hearability

The nominal zone location can also be combined with a signal propagation model to determine if a cell has incorrect errors. For a cell to be detectable at a given location, the received signal strength, including any receiver and processing gains, needs to be above the receiver noise floor and it must be sufficiently strong to be detectable above the interference. At the nominated location the signal strength can be estimated based on a radio propagation model. Optionally the model can include the effects of co-channel interference. Optionally the model can take into account the effect of adjacent channel interference. The estimated signal strength is compared to the receiver sensitivity. If the signal is weaker than this value, then the cell potentially has incorrect coordinates. If the signal is sufficiently strong, it is then compared to the combined estimated effects of co-channel and adjacent channel interference. If the signal is not sufficiently strong relative to the interference, then the cell coordinates may be in error.

In the above example for a GSM network, the estimated signal strength at the nominated location is -119.1dBm. The receiver sensitivity for a GSM mobile is approximately -104dBm. Thus the estimated signal strength is 15.1dBm, which is too weak to be detected and thus the cell may have incorrect coordinates. If the signal were above the receiver sensitivity, then the interference, if being estimated, could then be evaluated. In GSM the signal needs to be 9dB stronger than the nett interference to be detected.

Incidental Detection

Measurements made of cell signals are commonly reported only with partial cell identifiers. For example in GSM, neighbour cells are usually identified only by a BSIC and ARFCN. Serving cells are identified via their Cell ID. The actual cell associated with each partially identified measurement is determined by searching for a match to the partial identity within the vicinity of the serving cell that has been fully identified via a cell ID. If the neighbour cell has incorrect coordinates, then the search to find the cell may fail or result in the measurement being associated with the wrong cell. As such, the failure to find a cell to match reported cell identifiers can be an indication of a cell with coordinate errors. Similarly, if a serving cell has incorrect coordinates, one or more neighbour cells may not be able to be fully identified based on the BSIC and ARFCN because of the coordinate error. Thus a coordinate error may manifest via the detection of an unknown cell which will be resolved via a correction to a cell's coordinates once the root cause is identified.

Efficient Collection of Network Measurements

In one aspect of the invention, the system can optionally leverage the spare capacity in existing messages and/or use already established communication sessions to report information about the radio network for use in one or more of the methods described above. In many communications networks the protocols available for transmitting the zone status updates or location data are fixed in size, for example SMS in GSM. The status update and location messages do not necessarily use all of the available space. There are also session based communications protocols wherein there is a network bandwidth cost associated with setting up the session, for example USSD in GSM. Having set up a session to send a message, the marginal cost of sending extra data is low. An advantage of the present invention is to leverage the available space or session to send information about the observed radio network at no extra cost in terms of network capacity. In systems where the message length is variable, the extra information required to support methods according to aspects of the present invention can still be appended to status and location update messages for a small marginal cost. The network capacity cost of setting up a connection is often such that sending a small amount of extra data will not significantly impact the system.

This information can be used to support the detection of inconsistencies between the network database and the actual configuration. The information sent can include the identity if serving cell being used by the mobile, and for each cell heard by the mobile: full (e.g. CID + LAC) and partial cell identifiers (e.g. BSIC, PSC), channel / frequency, signal strength, and / or variation in signal strength. The data can be the raw measurements or filtered (e.g. averaged).

In the process of operating a location or zone based service, a subscriber's handset or mobile terminal periodically exchanges messages with a network based server. For example, in a home zone service operating as described previously, typically each time the subscriber moves either into or out of the zone, a message is sent notifying the server. A further advantage of combining data into this message is the spatial coverage that such a spatial trigger provides. The network data gathered will derive from a cross the network coverage area.

For a location service there will be a message sent to the server containing either the data in support of a location request or the coordinate estimate generated in the mobile.

As an example of the spare capacity available in a fixed size message format, consider a zone-based location system in which the mobile notifies the status (in/out) of its zones to a server using SMS. In GSM the SMS payload is a fixed size of 140 octets. As illustrated in Table 23 below, 1 octet is reserved to indicate the type of message, one octet enables up to 8 zone statuses (IN or OUT) to be reported leaving 138 octets available for reporting observations of the radio network.

Table 23

Msg Type	**Zone State**	**Radio network observation data**
1 octet	1 octet	138 octets

Throughout the specification and the claims that follow, unless the context recquires otherwise, the words "comprise" and "include" and variations such as "comprising" and "including" will be understood to imply the inclusion of a stated integer or group of integers, but not the exclusion of any other integer or group of integers.

The reference to any prior art in this specification is not, and should not be taken as, an acknowledgement of any form of suggestion that such prior art forms part of the common general knowledge

THE CLAIMS:

1. A method for detecting an inconsistency between a radio communications network and a network database, the method comprising:

   receiving from a mobile radio terminal in the radio communications network, at least one measurement of at least one parameter from the mobile radio communications network;

   comparing the at least one measurement with corresponding data in the network database; and

   determining that the at least one measurement is inconsistent if the at least one measurement is different to the corresponding data in the network database.

2. A method as claimed in claim 1 further comprising the step of calculating a metric associated with the at least one measurement using data from the network database, and comparing the calculated metric with a threshold.

3. A method as claimed in claim 2 further comprising determining that the at least one measurement is different to the corresponding data in the network database if the calculated metric exceeds the threshold.

4. A method as claimed in claim 1 further comprising making a hypothesis that a parameter of the mobile radio communications network is not present in the mobile radio communications network even though data in the network database indicates that the parameter is present.

5. A method as claimed in claim 4 further comprising, if the at least one measurement does not contradict the hypothesis, considering data that supports the hypothesis.

6. A method as claimed in claim 4 further comprising considering data that supports the hypothesis.

7. A method as claimed in claim 6 wherein the step of considering data that supports the hypothesis comprises determining whether the mobile radio terminal is in a given zone.

8. A method as claimed in claim 7 wherein, if the mobile radio terminal is determined to be in the given zone, the method further comprising comparing the at least one measurement with data in the network database corresponding to one or more expected measurements that would be expected to be obtained by the mobile radio terminal in the given zone.

9. A method as claimed in claim 8 further comprising determining that there is an inconsistency between the radio communications network and the network database if the step of comparing the at least one measurement with data in the network database corresponding to the one or more expected measurements indicates a difference.

10. A method as claimed in claim 9 further comprising accumulating a plurality of measurements over time and determining that there is an inconsistency between the radio communications network and the network database if the difference between the accumulated

measurements and the one or more expected measurements exceeds a predetermined threshold.

11. A method as claimed in claim 10 wherein the hypothesis is that the radio communications network contains a non-operational cell.

12. A method as claimed in claim 1 wherein the at least one measurement is received from the mobile radio terminal using spare capacity in an already established communications session.

13. A method as claimed in claim 12 wherein a plurality of measurements are received from a plurality of mobile radio terminals within the radio communications network.

14. A network processor in a radio communications network having at least one radio parameter, at least one mobile radio terminal, and a network database, the network database storing data corresponding to the at least one radio parameter, the network processor comprising:

a receiver for receiving from the mobile radio terminal in the radio communications network, at least one measurement of the at least one parameter;

a comparator for comparing the at least one measurement with the corresponding data in the network database; and

a means for determining that the at least one measurement is inconsistent if the at least one measurement is different to the corresponding data in the network database.

15. A radio communications network comprising a network processor as claimed in claim 14.

16. A method for detecting a non-operational cell in a radio communications network, the method comprising:

    receiving at least one measurement, including data relating to at least one cell, from a mobile radio terminal in the radio communications network;

    determining whether the mobile radio terminal is in a given zone; determining whether the at least one cell is reported; updating evidence that the at least one cell is not operating; determining whether the updated evidence exceeds a predetermined threshold; and

    determining that the at least one cell is not operational if the updated evidence exceeds the predetermined threshold.

17. A method as claimed in claim 16 further comprising for each cell reported in the at least one measurement, resetting evidence against the at least one cell not operating.

18. A method as claimed in claim 16 wherein the step of resetting evidence against the at least one cell not operating comprises setting an accumulated unreported cell cost to zero and setting a cell count to zero.

19. A method as claimed in claim 17 wherein for each cell unreported in the at least one measurement, the step of updating evidence that the at least one cell is not operating comprises computing an unreported cell cost for the at least one cell and adding the computed unreported cell

cost to the accumulated unreported cell cost and incrementing the cell count.

20. A method as claimed in claim 18 wherein the step of determining whether the updated evidence exceeds the predetermined threshold comprises determining whether the accumulated unreported cell cost is greater than the predetermined threshold.

21. A method as claimed in claim 19 wherein the at least one cell is determined to be potentially non-operational if the accumulated unreported cell cost is greater than the predetermined threshold.

22. A network processor for use in a radio communications network having at least one cell in a zone and at least one mobile radio terminal in the radio communications network, the network processor comprising:

a receiver for receiving at least one measurement, including data relating to at least one cell, from a mobile radio terminal in the radio communications network;

a means for determining whether the mobile radio terminal is in a given zone; determining whether the at least one cell is reported;

a means for updating evidence that the at least one cell is not operating;

a means for determining whether the updated evidence exceeds a predetermined threshold; and

a means for determining that the at least one cell is not operational if the updated evidence exceeds the predetermined threshold.

23. A radio communications network comprising a network processor as claimed in claim 22.

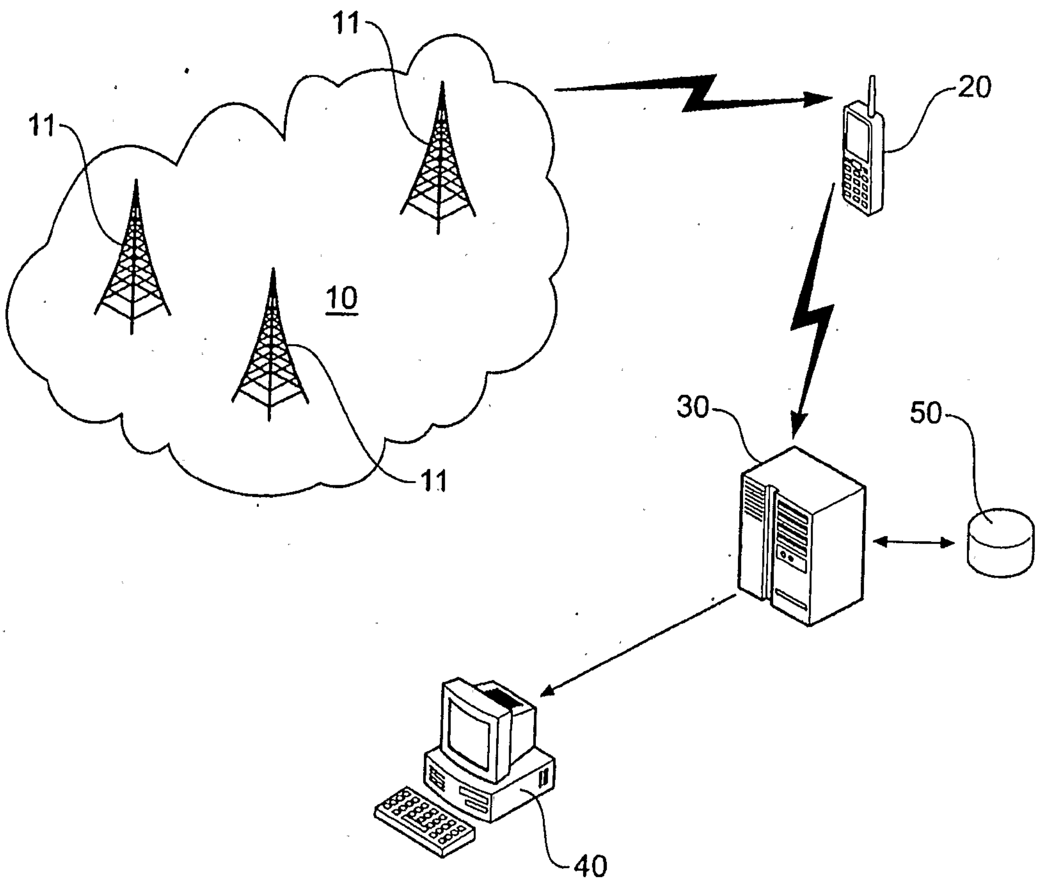


Figure 1

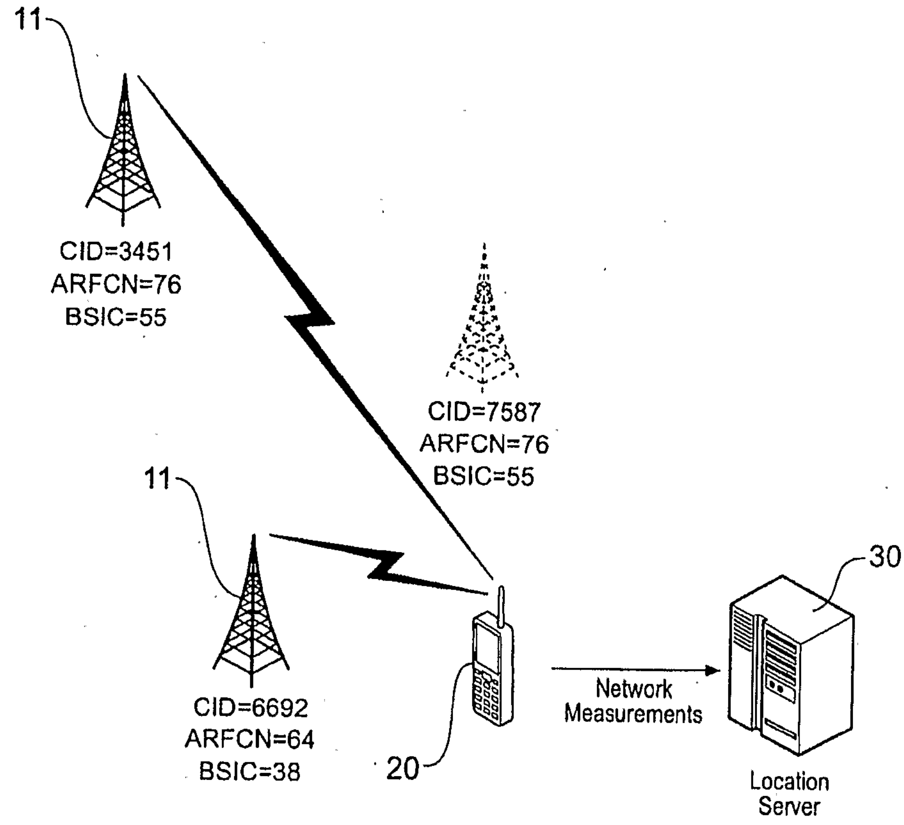

11
CID=3451
ARFCN=76
BSIC=55
CID=7587
ARFCN=76
BSIC=55
11
30
CID=6692
ARFCN=64
BSIC=38
20
Network
Measurements
Location
Server

Figure 2

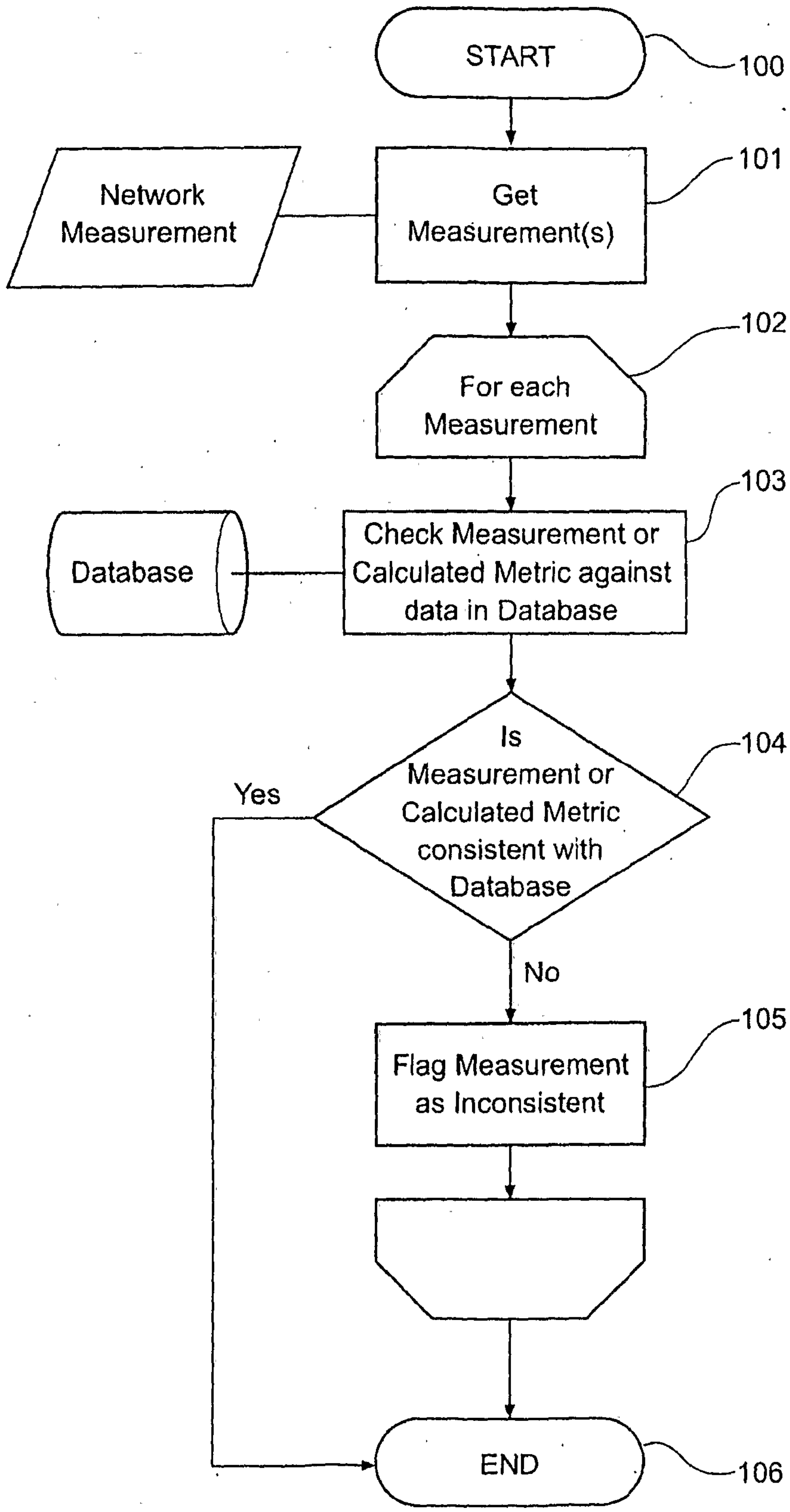

START
100
Network Measurement
Get Measurement(s)
101
For each Measurement
102
Database
Check Measurement or Calculated Metric against data in Database
103
Is Measurement or Calculated Metric consistent with Database
104
Yes
No
Flag Measurement as Inconsistent
105
END
106

Figure 3

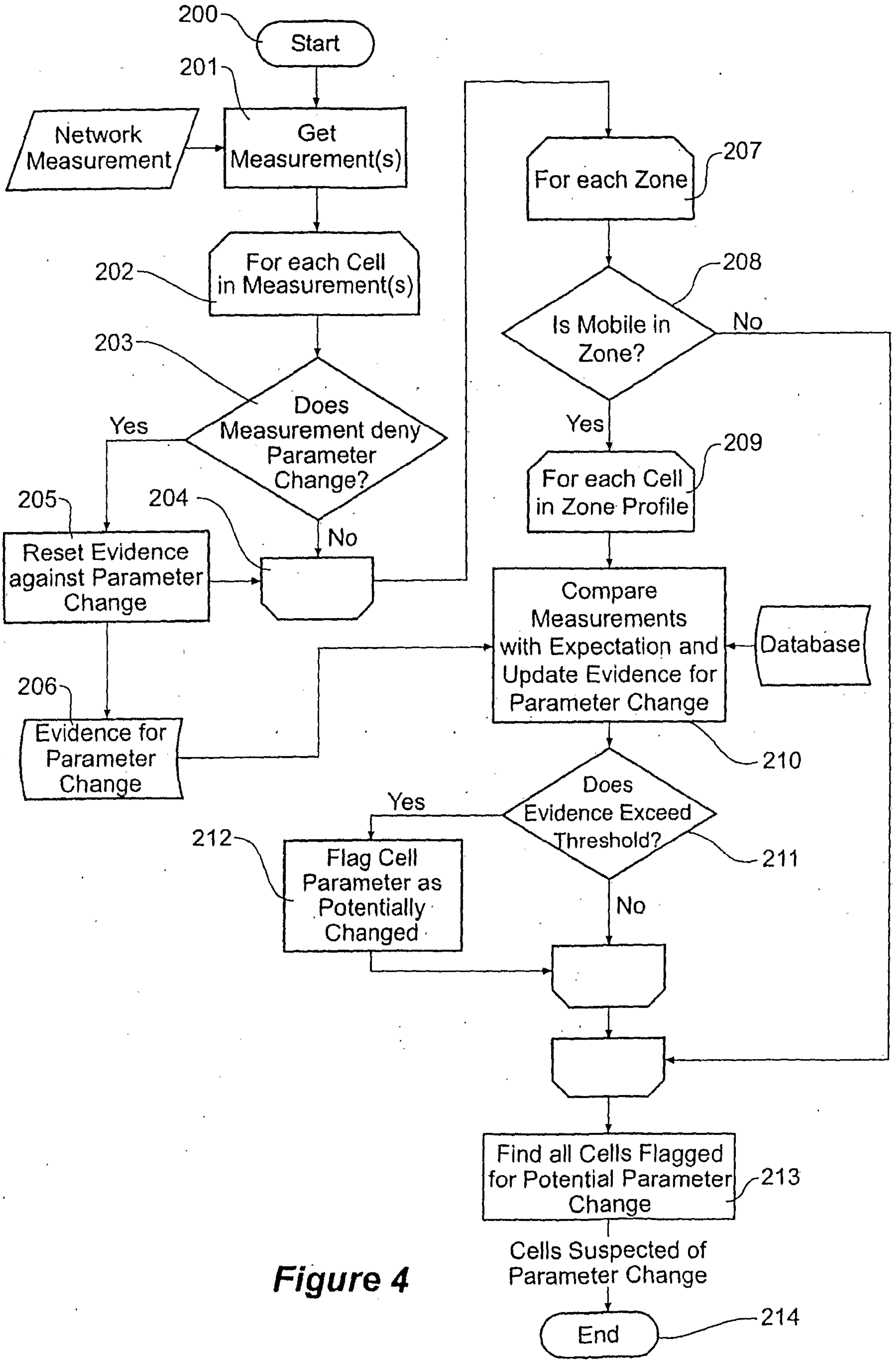

200
Start
201
Network Measurement
Get Measurement(s)
202
For each Cell in Measurement(s)
203
Does Measurement deny Parameter Change?
Yes
No
204
205
Reset Evidence against Parameter Change
206
Evidence for Parameter Change
207
For each Zone
208
Is Mobile in Zone?
No
Yes
209
For each Cell in Zone Profile
Compare Measurements with Expectation and Update Evidence for Parameter Change
Database
210
Does Evidence Exceed Threshold?
211
Yes
No
212
Flag Cell Parameter as Potentially Changed
Find all Cells Flagged for Potential Parameter Change
213
Cells Suspected of Parameter Change
End
214

Figure 4

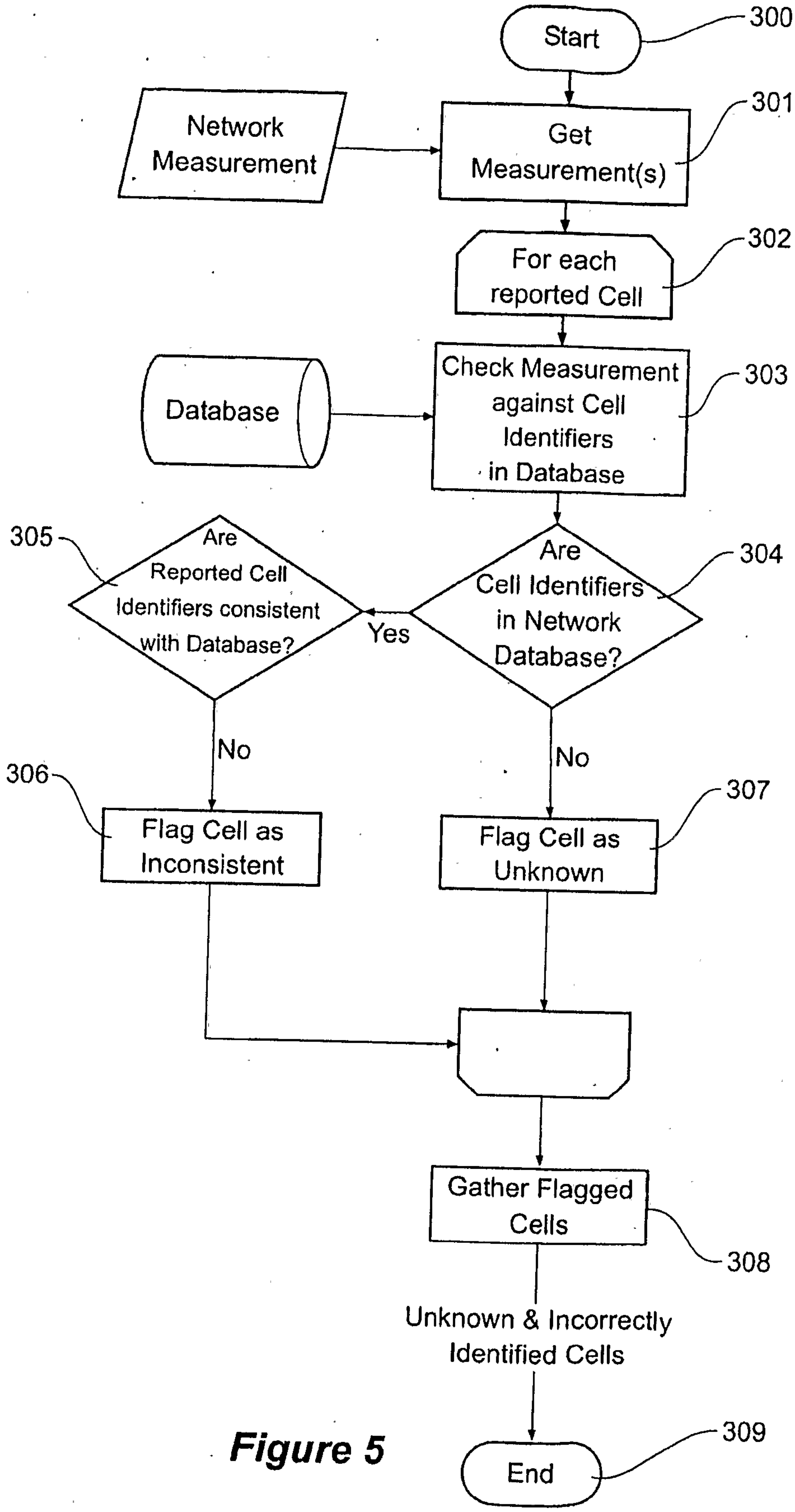

Start
300
Network Measurement
Get Measurement(s)
301
For each reported Cell
302
Database
Check Measurement against Cell Identifiers in Database
303
305
Are Reported Cell Identifiers consistent with Database?
Yes
Are Cell Identifiers in Network Database?
304
No
No
306
Flag Cell as Inconsistent
Flag Cell as Unknown
307
Gather Flagged Cells
308
Unknown & Incorrectly Identified Cells
309
End

Figure 5

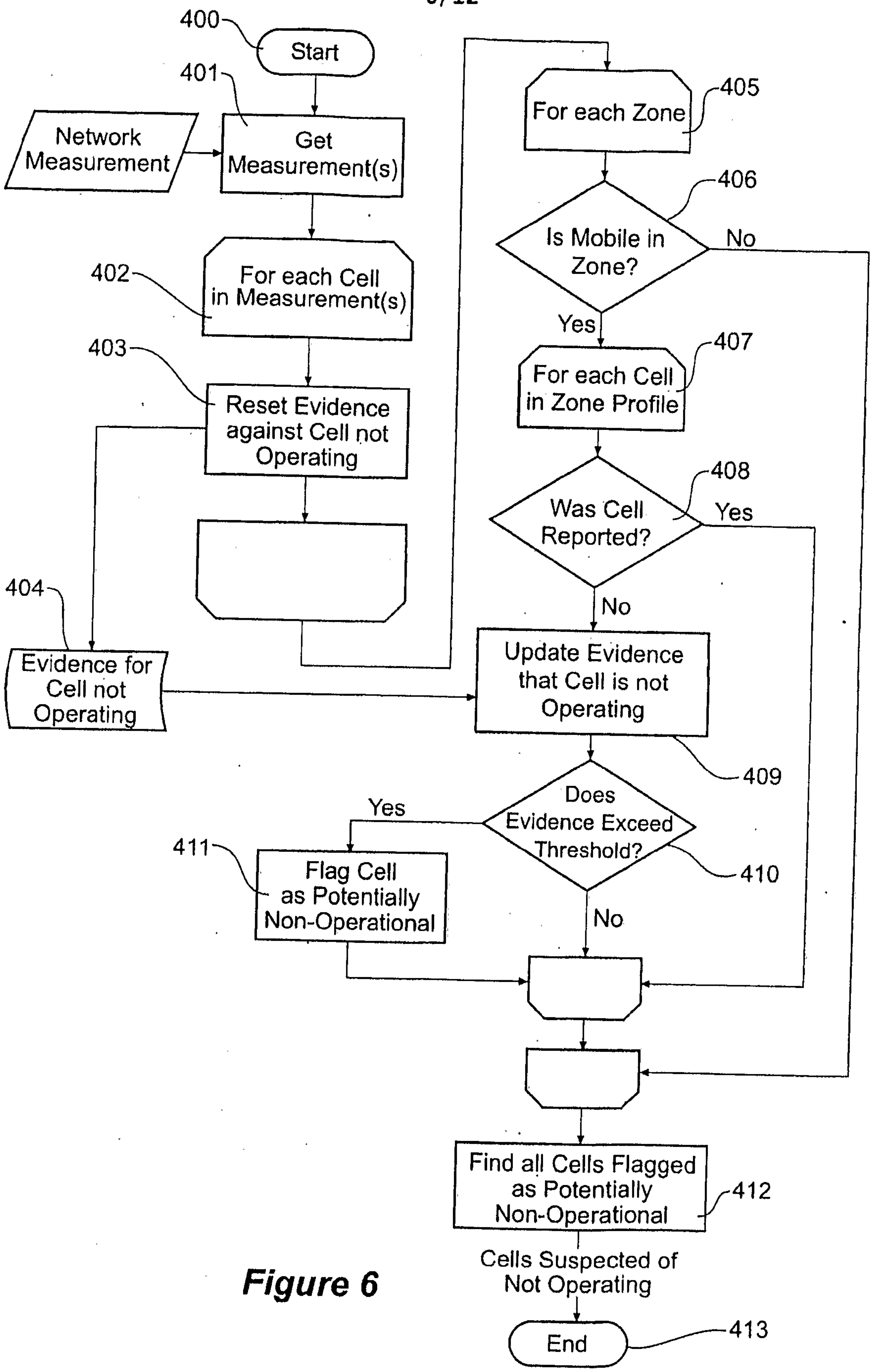

400
Start
401
Network Measurement
Get Measurement(s)
402
For each Cell in Measurement(s)
403
Reset Evidence against Cell not Operating
404
Evidence for Cell not Operating
405
For each Zone
406
Is Mobile in Zone?
No
Yes
407
For each Cell in Zone Profile
408
Was Cell Reported?
Yes
No
Update Evidence that Cell is not Operating
409
Does Evidence Exceed Threshold?
410
Yes
No
411
Flag Cell as Potentially Non-Operational
Find all Cells Flagged as Potentially Non-Operational
412
Cells Suspected of Not Operating
End
413

Figure 6

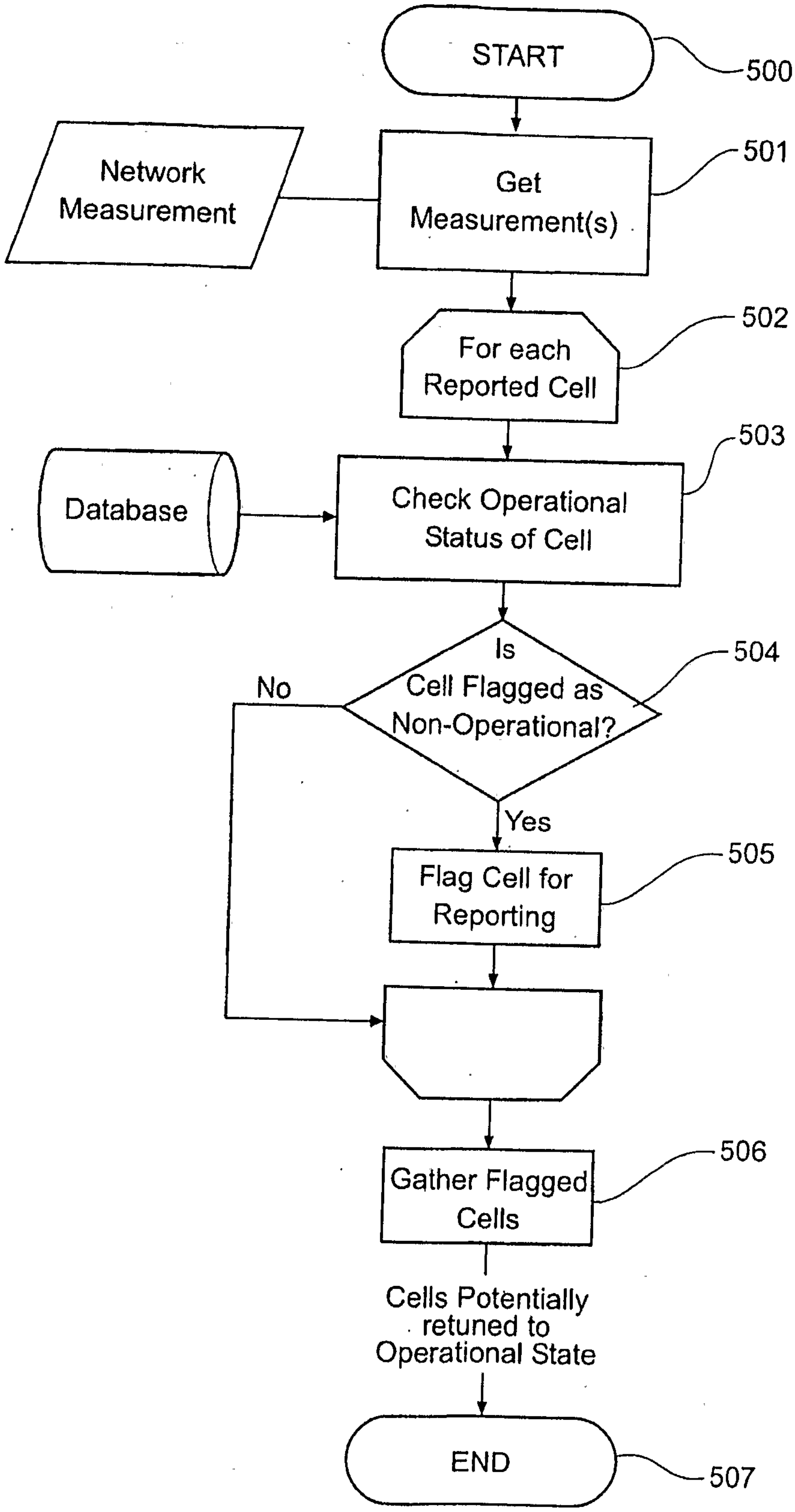

START
500
Network Measurement
Get Measurement(s)
501
For each Reported Cell
502
Database
Check Operational Status of Cell
503
Is Cell Flagged as Non-Operational?
504
No
Yes
Flag Cell for Reporting
505
Gather Flagged Cells
506
Cells Potentially retuned to Operational State
END
507

Figure 7

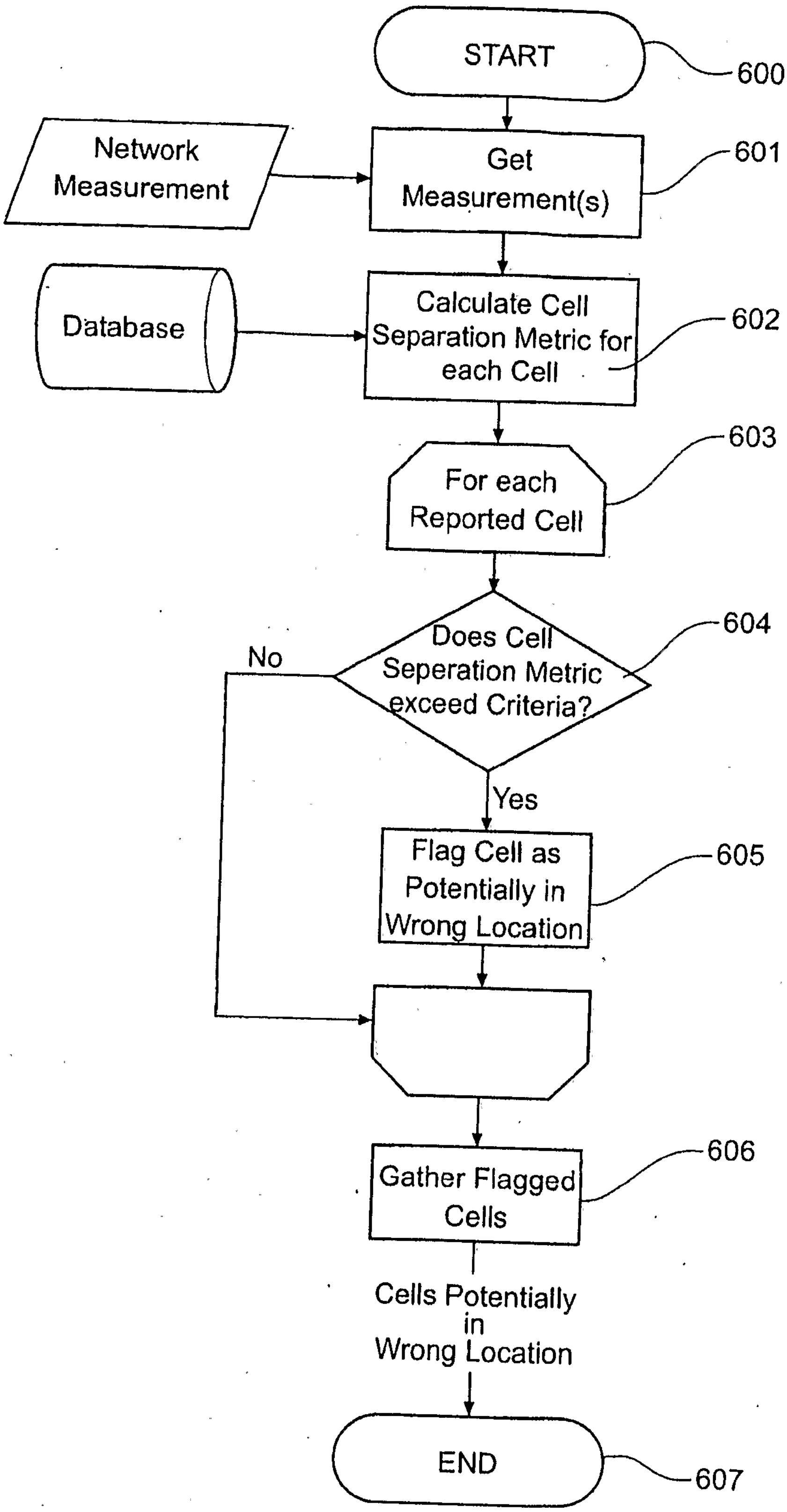
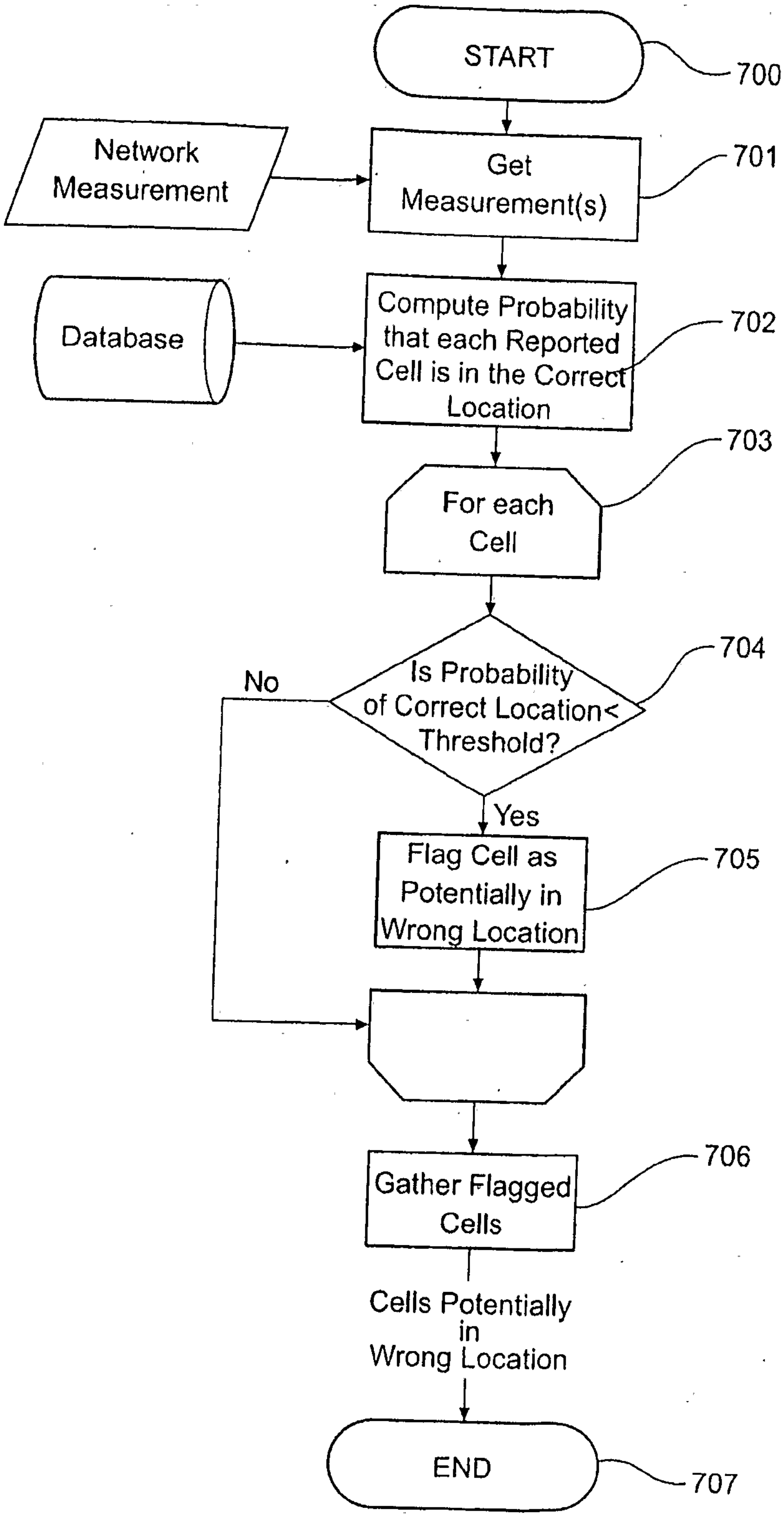

START
600
Network Measurement
Get Measurement(s)
601
Database
Calculate Cell Separation Metric for each Cell
602
For each Reported Cell
603
Does Cell Seperation Metric exceed Criteria?
604
No
Yes
Flag Cell as Potentially in Wrong Location
605
Gather Flagged Cells
606
Cells Potentially in Wrong Location
END
607

Figure 8



START
700
Network Measurement
Get Measurement(s)
701
Database
Compute Probability that each Reported Cell is in the Correct Location
702
For each Cell
703
No
Is Probability of Correct Location< Threshold?
704
Yes
Flag Cell as Potentially in Wrong Location
705
Gather Flagged Cells
706
Cells Potentially in Wrong Location
END
707

Figure 9

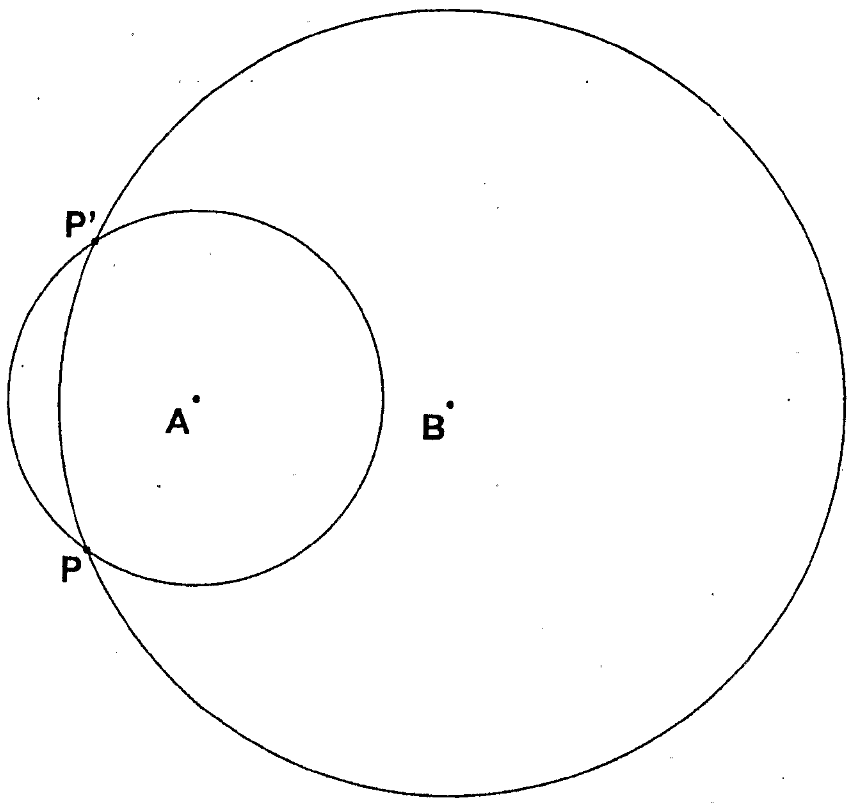


Figure 10A

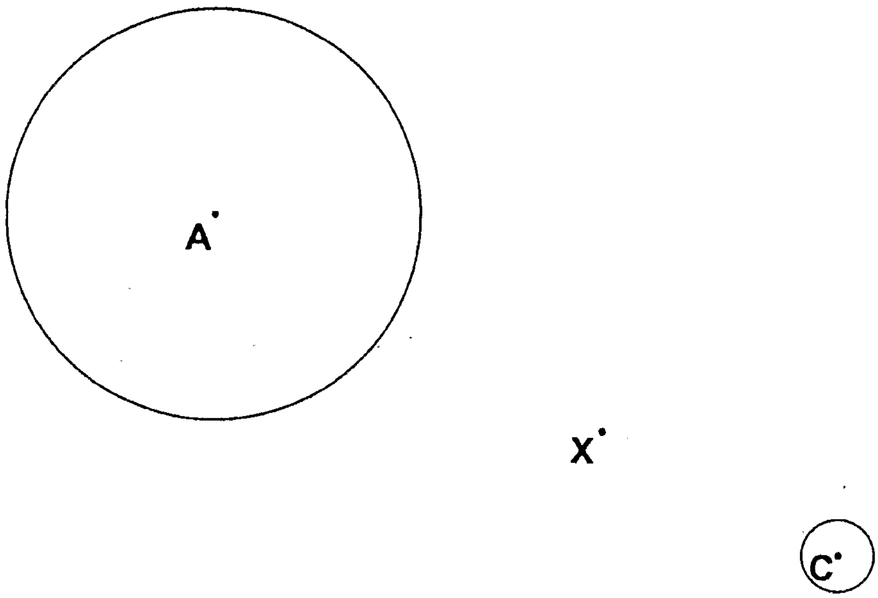


Figure 10B

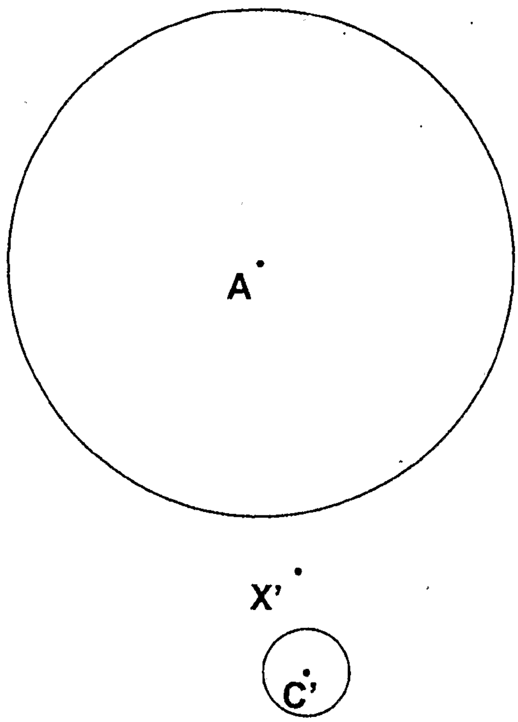


Figure 10C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001577

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

H04Q 7/34 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
dwpi (radio, wireless, network, error, fault, inconsistency, discrepancy, mobile station, parameter, metric, stored, database, cell, zone, threshold, measurement, measured value0

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/0147362 A1 (DICK et al.) 7 August 2003 Paragraph 18, figs. 5a, 5b	1-23
A	US 6947734 B1 (TOUBASSI) 20 September 2005 The whole document	
A	US 2004/0203717 A1 (WINGROWICZ et al.) 14 October 2004 The whole document	
A	US 6567381 B1 (JEON et al.) 20 May 2003 The whole document	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 November 2006	28 NOV 2006

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	**J. LAW** Telephone No : (02) 6283 2179

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 1993/015569 (COMARCO INCORPORATION) 5 August 1993 The whole document	

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2003147362	AU	2003212929	CA	2475495	CN	1628423
		EP	1479175	EP	1675279	JP	2006081200
		KR	2004004156	KR	2005009111	KR	2005009993
		MX	PA04007593	NO	20043635	WO	03067769
US	6947734						
US	2004203717						
US	6567381						
WO	1993/015569						

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX