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(54) **Title**: CLOSENESS POSITIONING IN WIRELESS NETWORKS

(57) **Abstract**: The present invention provides methods and apparatus for determining the closeness of neighbor cells to a user terminal. A user terminal performs measurements and sends its measurements to a closeness determination node. The closeness determination node computes a closeness fingerprint based on measurements received from the user terminal, and stores the closeness fingerprint in a closeness database. When the closeness of a set of neighbor cells to a user terminal is to be determined, the user terminal may perform fingerprint measurements and send the fingerprint measurements to the closeness determination node. The closeness determination node may then select a set of neighbor cells that are closest to the user terminal based on the comparison of the received fingerprint measurements to the closeness fingerprints stored in the closeness database.

CLOSENESS POSITIONING IN WIRELESS NETWORKS

TECHNICAL FIELD

The present invention relates generally to neighbor cell measurements in a wireless communication network and, more particularly, to methods and apparatus enabling user terminals to determine closeness of cells for purposes of performing cell measurements on the closest cells.

BACKGROUND

Release 10 of the Third Generation Partnership Project (3GPP) standard known as Long Term Evolution (LTE) supports heterogeneous networks. In heterogeneous networks, a mixture of cells of different size and overlapping coverage areas are deployed. For example, a heterogeneous network may deploy small cells (e.g., pico cells, micro cells) and/or very small cells (e.g., femto cells) within the coverage area of a macro cell served by relatively high power base stations. One consequence of heterogeneous networks is an increasing number of cells. A user terminal is therefore likely to be surrounded by many more cells than in the case of a conventional network with macro cells only. This densification, in turn, means that a user terminal may be required to perform many more cell measurements. The increased cell measurement load will result in larger battery drain rate for the user terminal, and an increased signaling load on the radio access network (RAN) that consumes bandwidth and increases interference.

One way to mitigate the increased cell measurement load is to avoid measuring every one of the increasing number of neighbor cells. By measuring less than all the neighboring cells, the signaling and user terminal measurement load will be decreased. In this case, the user terminal must select the neighbor cells on which it performs measurements. One solution is to perform measurements on only the closest cells. Accordingly, there is a need for new techniques to determine the closest cells using as little signaling and user terminal measurement resources as possible.

SUMMARY

The present invention provides a method for determining the closeness of neighbor cells to a user terminal. In exemplary embodiments of the invention, user terminals within the network perform fingerprint measurements for building a closeness database and send the fingerprint measurements to a closeness determination node. The fingerprint measurements may include, for example, the cell ID, received signal strength, and timing advance of a plurality of neighbor cells. Each set of fingerprint measurements is associated with one or more closeness indicators. Each closeness indicator indicates whether the user terminal providing the fingerprint measurement is close to a particular cell. The closeness determination node generates closeness fingerprints

based on the fingerprint measurements having the same closeness indicators or measurement components. The closeness fingerprints are stored in the closeness database along with corresponding closeness indicators for later use in determining cells that are close to a user terminal.

When the closeness of a set of neighbor cells to a user terminal is to be determined, the user terminal may perform fingerprint measurements for closeness determination and sends the fingerprint measurements to the closeness determination node. The closeness determination node determines which cells to the user terminal are close by comparing the received fingerprint measurements to the stored closeness fingerprints. Based on the comparison, the closeness determination node generates a list of neighbor cells that are closest to the user terminal and sends the neighbor cell list to the user terminal. The neighbor cell list may, for example, include the cell IDs for the selected neighbor cells. Upon receipt of the neighbor cell list from the closeness determination node, the user terminal may perform signal strength measurements or other signal quality measurements on the neighbor cells in the neighbor cell list.

According to one aspect of the invention, a method is provided for building a closeness database for use in making closeness determinations. The method may be implemented by a closeness determination node. The closeness determination node receives a set of fingerprint measurements from each of one or more user terminals and associates a closeness indicator with each set of fingerprint measurements. The closeness indicator indicates a closeness of a corresponding one of the user terminals to a given access node. The closeness determination node generates a closeness fingerprint from two or more sets of said fingerprint measurements selected based on the closeness indicator and measurement components, and stores the closeness fingerprint and associated closeness indicator in a neighbor cell database.

According to another aspect of the present invention, a method is provided for determining the closeness of one or more neighbor cells to a user terminal. The method may be performed by a closeness determination node. The closeness determination node receives a set of fingerprint measurements from the user terminal corresponding to one or more cells. The closeness determination node compares the received set of fingerprint measurements to one or more stored closeness fingerprints in a neighbor cell database. Based on the comparison, the closeness determination node generates a list of neighbor cells and corresponding closeness indicators.

According to another aspect of the present invention, a method is provided for performing measurements on neighbor cells. The method may be implemented by a user terminal. The user terminal performs fingerprint measurements on one or more cells in the proximity of the user terminal. Those cells may include the user terminal’s own cell and one or more neighbor cells. The user terminal sends the fingerprint measurements to a closeness determination node. In response to the measurement report, the user terminal receives a neighbor cell list from the closeness determination node. The neighbor cell list comprises a list of the closest neighbor cells to the user terminal, which is determined by the closeness determination node based on the fingerprint measurements. The user terminal stores the neighbor list in memory. Subsequently, the user terminal performs second measurements on the closest neighbor cells in the neighbor cell list.

Other embodiments of the invention comprise a closeness determination node configured to create a closeness database and to determine the closeness of neighbor cells to a user terminal as herein described. Still other embodiments comprise a user terminal configured to perform neighbor cell measurements as herein described.

By identifying the cells closest to the user terminal, the present disclosure reduces the measurement load on the user terminal and the signaling load on the network.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the network architecture for a LTE network.

Figure 2 illustrates an exemplary management system architecture for an LTE network.

Figure 3 illustrates an exemplary handover procedure.

Figure 4 illustrates a high level positioning architecture for LTE networks.

Figure 5 illustrates an exemplary network environment including four cells and four user terminals.

Figure 6 illustrates distance of the user terminals to a cell in the network environment shown in Figure 5.

Figure 7 illustrates an exemplary procedure implemented by a closeness determination node for closeness database build-up.

Figure 8 illustrates an exemplary procedure implemented by a closeness determination node for closeness determination using a closeness database.

Figure 9 illustrates an exemplary procedure implemented by a user terminal for performing neighbor cell measurements.

Figure 10 illustrates an exemplary user terminal.

Figure 11 illustrates an exemplary closeness determination node.

DETAILED DESCRIPTION

Referring now to the drawings, exemplary embodiments of the invention will be described in the context of a Long Term Evolution (LTE) network 10. The Third Generation Partnership Project (3GPP) is currently working on standardization of Release 12 of the LTE standard. The architecture of the LTE network 10 is shown in Figure 1. For simplicity, some elements of the LTE network 10 not necessary for understanding the principles described herein are omitted. Those skilled in the art will appreciate, however, that a network using the principles and techniques herein described may include other elements not explicitly disclosed. Further, the principles and technique herein described may be practiced in other types of networks, such as Wideband Code Division Multiple Access (WCDMA) networks.

A typically LTE network 10 comprises an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) 15 and an Evolved Packet Core (EPC) network 20. The E-UTRAN 15 includes a plurality of base stations (BSs) 25 for communicating with user terminals. In LTE, the BSs 25 are referred to as NodeBs (NBs) and Evolved NodeBs (eNodeBs or eNBs). User terminals are referred to as user equipment (UE). The term user terminal is used herein synonymously with the terms user terminal, mobile terminal, and wireless terminal. The EPC network 20 includes a Mobility Management Entity (MME) 30 and Serving Gateway (S-GW) 35. Although shown as a single unit, the MME 30 and S-GW 35 may reside in different nodes.

The management system 40 for the exemplary LTE network 10 is shown in Figure 2. The management system comprises node elements (NEs) 45, domain managers (DMs) 50, and a Network manager (NM) 55. The node elements 45 within the network 10, including the BSs 25, are managed by a corresponding domain manager 50. The domain manager may comprise an operation and support system (OSS). A domain manager 50 may further be managed by a network manager 55. The interface between two node elements 45 is referred to as the X2 interface, whereas the interface between two domain managers 50 is referred to as Itf-P2P interface. The management system may configure the node elements 45, as well as receive observations associated with features in the node elements 45. For example, a DM observes and configures node elements 45, while a network manager 55 observes and configures a domain manager 50, as well as a node element 45 via a domain manager 50.

LTE neighbor cell measurements, mobility management node, and associated signaling

User terminal signal level measurements

In order to support different functions such as mobility (e.g. cell selection, cell reselection, handover, RRC re-establishment, connection release with redirection etc.), minimization of drive tests, self-organizing network (SON), positioning etc., the user terminal is required to perform measurements on the signals transmitted by the serving cell and the neighboring cells. Prior to performing such measurements, the user terminal has to identify a cell and determine its physical cell identity (PCI). The PCI determination is also a type of measurement. In addition, the user terminal performs signal strength or signal quality measurements on a neighbor cell. Examples of signal strength measurements which can be performed by the user terminal are RSRP (Reference Signal Received Power) and/or RSRQ (Reference Signal Received Quality) in E-UTRAN, Common Pilot Channel (CPICH) RSCP and/or CPICH energy to noise ratio (Ec/No) in UTRAN, carrier Received Signal Strength Indicator (RSSI) measurements in Global System for Mobile

Communication (GSM) EDGE (Enhanced Data Rates for GSM Evolution) radio access networks (GERAN), and pilot signal strength for CDMA2000 High Rate Packet Date (HRPD) networks. In connected mode, the user terminal reports the performed measurements to the serving BS 25.

Neighbor cell measurements for handover purposes

In intra frequency operations, handover candidates are regularly monitored by the user terminal. The user terminal synchronizes to a candidate neighbor cell via synchronization signals, and identifies the cell by physical signal sequences that are associated to a physical cell identifier (PCI). Furthermore, the PCI is associated with a cell-specific reference sequence (pilot), and the user terminal estimates the RSRP as the average power over the reference sequence symbols. In addition, the user terminal determines the RSRQ as the RSRP divided by the total received power.

In inter-frequency operations, similar procedures are followed, with the only difference being that the user terminal needs to be configured to use the resources on which inter-frequency measurements are to be taken. Namely, in inter-frequency operations the user terminal is not able to autonomously search for neighbor cells and report their PCI to the serving BS 25.

In order to configure a user terminal to perform measurements and report measurement results, the following measurement events have been defined as part of the LTE design specifications (see TS 36.331 for more details):

- Event A1 (Serving cell becomes better than threshold)
- Event A2 (Serving cell becomes worse than threshold)
- Event A3 (Neighbor cell becomes offset better than the Primary cell (PCell))
- Event A4 (Neighbor cell becomes better than threshold)
- Event A5 (Primary Cell (PCell) becomes worse than threshold1 and neighbor cell becomes better than threshold2)
- Event A6 (Neighbor cell becomes offset better than a Secondary Cell (SCell))
- Event B1 (Inter radio access technology (RAT) neighbor cell becomes better than threshold)
- Event B2 (PCell becomes worse than threshold1 and inter RAT neighbor becomes better than threshold2)

Similar events are also defined for WCDMA technologies.

Once configuration of detection of such events at the user terminal is completed and upon detection of appropriate conditions, the user terminal reports the measurement results via Radio Resource Control (RRC) signaling corresponding to the monitored event. However, in LTE, more conditions apply to measurement restrictions in cases of user terminals served by heterogeneous networks where almost blank subframes (ABS) are used.

Neighbor cell measurements in Heterogeneous Networks

In Rel-8 of the LTE standard, the signaling of the neighbor cell list to the user terminal to aid measurements is optional. This means the user terminal requirements on measurements are applicable even if the neighbor cell list is not signaled to the user terminal. Therefore, the user terminal blindly and autonomously detects the neighbor cells, performs measurements on the identified cells, and reports the measurement results to the serving BS 25.

In Rel-10 of the LTE standard, the time domain enhanced Inter-cell Interference Coordination (eICIC) has been specified. In the time domain scheme, resource partitioning in the time domain between an aggressor cell and a victim cell is used to mitigate the interference towards the victim cells. This mechanism is being further enhanced in Release 11 of the LTE standard.

According to the time domain eICIC scheme, the subframe utilization across different cells is coordinated in time through backhaul signaling, i.e., over X2 interface between BSs 25. The subframe utilization is expressed in terms of a time domain pattern of low interference subframes or 'low interference transmit pattern'. These patterns are called as Almost Blank Subframe (ABS) patterns. The Almost Blank Subframes (ABSs) are configured in an aggressor cell (e.g., macro cell) and are used to protect resources in subframes in the victim cell (e.g., pico cell) receiving strong inter-cell interference.

ABSs are subframes configured in an aggressor cell with reduced transmit power or no transmission power and/or reduced activity on some of the physical channels. In an ABS, the basic common physical channels such as common reference signal (CRS), Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS), Physical Broadcast Channel (PBCH) and System Information Block 1 (SIB1) are transmitted to ensure the operation of the legacy user terminals.

The ABS pattern can be a Multimedia Broadcast Multicast Services Single Frequency Network (MBSFN) pattern and non-MBSFN pattern. In a non-MBSFN pattern, an ABS can be configured in any subframe (MBSFN or non-MBSFN configurable subframes). In a MBSFN pattern, an ABS can be configured in only MBSFN configurable subframes (i.e., subframes 1, 2, 3, 6, 7 and 8 in FDD (Frequency Division Duplexing) and subframes 3, 4, 7, 8 and 9 in TDD (Time Division Duplexing)).

As part of the eICIC solution, the serving BS 25 signals to the user terminal one or more measurement patterns (aka measurement resource restriction pattern) to inform the user terminal about the resources or subframes which the user terminal should use for performing measurements on a target victim cell (e.g., serving pico cell and/or neighboring pico cells). While such signaling was done in Release 8 only for inter-frequency measurements, with the introduction of eICIC in Release 10, such signaling also needs to be done for intra-frequency measurements.

The measurement patterns are signaled to the user terminal via RRC signaling in RRC_CONNECTED state. In later releases, the measurement pattern may also be configured in RRC_IDLE state. A measurement pattern is typically a subset of an ABS pattern configured in an aggressor cell. There are different measurement patterns depending on the type of the measured cell (serving or neighbor cell) and measurement type (e.g., Radio Resource Management (RRM), Radio Link Monitoring (RLM), Channel State Indication (CSI), etc.). More specifically, in Release 10 there are three kinds of measurement patterns that may be configured for the user terminal to perform measurements on a victim cell. More measurement patterns may be introduced in future releases.

- Pattern 1: A single RRM/RLM measurement resource restriction for the PCell.
- Pattern 2: A single RRM measurement resource restriction for all or indicated list of neighbor cells operating in the same carrier frequency as the PCell.
- Pattern 3: Resource restriction for CSI measurement of the PCell. If configured, two subframe subsets are configured per user terminal. The user terminal reports CSI for each configured subframe subset.

Together with the patterns above, the serving BS 25 also needs to signal a neighbor cell list to the user terminal, which is the list of cells for which measurements need to be taken within the measurement resources indicated in the measurement patterns.

Therefore, in eICIC for Release 10, a parameter called "measSubframeCellList" is signaled to the user terminal via RRC as defined in TS 36.331. It contains a list of cells for which the measurement patterns signaled via the "measSubframePatternNeigh" parameters are applied. The parameter, "measSubframePatternNeigh" is the 'time domain measurement resource restriction pattern' applicable for doing RSRP and RSRQ measurements in a neighbor cell on the indicated carrier frequency.

The standard also specifies that for cells included in the neighbor cell list (i.e., in measSubframeCellList), the user terminal shall assume that the subframes indicated by measSubframePatternNeigh are non-MBSFN subframes. Namely, measurements on cells in the signaled neighbor cell list and on resources signaled via the measurement patterns are subject to specific performance requirements applicable to non-MBSFN subframe measurements.

LTE Mobility in Connected Mode

The LTE handover preparation and execution can essentially be completed over the X2 interface without involving the packet core (e.g., EPC) network 20. However, some details needs to be aligned over the S1 interface. The handover mechanism can also be handled via the S1 interfaces forwarded by the MME.

Figure 3 illustrates an exemplary handover procedure when neither MME nor S-GW changes due to the handover. See 3GPP TS 36.300 for more details. Control plane steps include:

1) The source BS 25 configures the user terminal measurement procedures.
2) The user terminal is triggered to send MEASUREMENT REPORT by the rules set by, i.e., system information, specification etc.
3) The source BS 25 makes decision based on MEASUREMENT REPORT and RRM information to hand over (HO) the user terminal.
4) The source BS 25 issues a HANDOVER REQUEST message to the target BS 25 passing necessary information to prepare the HO at the target side
5) Admission Control may be performed by the target BS 25.
6) The target BS 25 prepares for HO with L1/L2 and sends the HANDOVER REQUEST ACKNOWLEDGE message to the source BS 25. The HANDOVER REQUEST ACKNOWLEDGE message includes a transparent container with *mobilityControlInformation* to be sent to the user terminal as an RRC message to perform the handover.
7) NOTE: As soon as the source BS 25 receives the HANDOVER REQUEST ACKNOWLEDGE message, or as soon as the transmission of the handover command is initiated in the downlink, user plane data forwarding may be initiated.
8) The target BS 25 generates the RRC message to perform the handover, i.e., *RRCConnectionReconfiguration* message including the *mobilityControlInformation*, to be sent by the source BS 25 towards the user terminal.
9) The source BS 25 sends the SN STATUS TRANSFER message to the target BS 25.
10) After receiving the *RRCConnectionReconfiguration* message including the *mobilityControlInformation*, the user terminal performs synchronisation with the target BS 25 and accesses the target cell via the Random Access Channel (RACH).
11) The target BS 25 responds with UL allocation and timing advance.
12) When the user terminal has successfully accessed the target cell, the user terminal sends the *RRCConnectionReconfigurationComplete* message (C-RNTI) to confirm the handover. The target BS 25 can now begin sending data to the user terminal.
13) The target BS 25 sends a PATH SWITCH REQUEST message to MME to inform the MME that the user terminal has changed cell.
14) The MME sends a MODIFY BEARER REQUEST message to the Serving Gateway.
15) The Serving Gateway switches the downlink data path to the target cell. The Serving Gateway sends one or more "end marker" packets on the old path to the source BS 25 and then can release any user-plane/TNL resources towards the source BS 25.
16) The Serving Gateway sends a MODIFY BEARER RESPONSE message to MME.

17) The MME confirms the PATH SWITCH REQUEST message with the PATH SWITCH REQUEST ACKNOWLEDGE message.
18) By sending the user terminal the CONTEXT RELEASE message, the target BS 25 informs success of HO to the source BS 25 and triggers the release of resources by the source BS 25.
19) Upon reception of the user terminal CONTEXT RELEASE message, the source BS 25 can release radio and C-plane related resources associated to the user terminal context. Any on-going data forwarding may continue.

Similar procedures are described for WCDMA technologies in TS23.060. For example, in section 6.9.2.2 signaling procedures for SRNS relocation are described.

Heterogeneous Network (HetNet) densification and closeness/proximity

Heterogeneous networks concern effects associated with networks where different kinds of cells are mixed. A problem with heterogeneous networks is that different cells may have different radio properties in terms of radio sensitivity, frequency band, coverage, output power, capacity, and acceptable load level, etc. Such problems can be an effect of the use of different radio base station (RBS) sizes (macro, micro, pico, femto), different revisions (different receiver technology, software quality), different vendors, and the purpose of a specific deployment. One area of concern for the present disclosure is the densification of the network node distribution that follows from home BS 25 deployment in heterogeneous networks.

One very important factor associated with dense heterogeneous networks is that of signaling load management, i.e., the issues associated with the control signaling between user terminals and the radio access network (RAN). Control signaling is becoming increasingly problematic due to the excessive signaling needs of various smartphones. Therefore, it is desirable to reduce such signaling as much as possible.

One type of signaling that should be reduced is associated with mobility and handovers. The user terminals continuously need to perform measurements on neighbor cells in order to determine if a handover to another cell is needed. Obviously, the need for such measurements increases when the network density is increased, i.e., there are more close cells that need to be monitored. This increases the signaling load between the RAN and the user terminals, since neighbor cell measurement results need to be reported to the RAN node that would determine if a handover is needed. The situation worsens if it is considered that mobility in heterogeneous networks may not be due to coverage, but it may be required for resource optimization such as load balancing or off-loading. Thus, a user terminal may be required to anticipate measurements for a given neighbor cell to enlarge the cell detection range in order to identify and report neighbor cells earlier. The latter requirement implies yet a further increase of signaling and measurements.

An associated problem is that each measurement may be costly for the user terminal. The reason is that the user terminals may need to perform signal processing as part of the measurement. Sometimes this signal processing is extensive and consumes a significant amount of hardware resources of the user terminal. If repeated, the effect may be an increased battery drain rate.

It would therefore be an advantage if the user terminal had the possibility to determine which neighbor cells that are the closest, by using simple means that consume little resources. It can be noted that hardware resources may be extensively used too, e.g., hardware support for search of signal energy during acquisition.

LTE positioning overview

In order to determine the closeness of a user terminal to a cell, a review of positioning technology is appropriate. Here LTE is used as an example - however similar techniques are available in other networks, such as WCDMA networks.

Positioning architecture and protocols in LTE

The three key network elements in an LTE positioning architecture are the location services (LCS) client, the LCS target and the LCS server. The LCS server is a physical or logical entity managing positioning for a LCS target by collecting measurements and other location information, assisting the user terminal in measurements when necessary, and estimating the LCS target location. A LCS client is a software and/or hardware entity that interacts with a LCS server for the purpose of obtaining location information for one or more LCS targets, i.e. the user terminals being positioned. The LCS client may reside in a network node, in a radio node, or in a user terminal. LCS clients may also reside in the LCS targets. An LCS client sends a request to the LCS server to obtain location information. The LCS server processes and serves the received requests, sends the positioning result, and optionally a velocity estimate to the LCS client. A positioning request can be originated from the terminal or the network.

DL positioning

Two positioning protocols operating via the radio network exist in LTE, the LTE positioning protocol (LPP) and LPPa. The LPP is a point-to-point protocol between a LCS server and a LCS target device, used in order to position the target device. LPP can be used both in the user and control plane, and multiple LPP procedures are allowed in series and/or in parallel thereby reducing latency. LPPa is a protocol between the BS 25 and LCS server specified only for control-plane positioning procedures, although it may assist user-plane positioning by querying BSs 25 for information and BS 25 measurements. The LTE Secure User Plane Location (SUPL) protocol may be used as a transport for LPP in the user plane. In the user plane with SUPL, a user terminal is typically referred to as SUPL Enabled Terminal (SET), the LCS platform is typically referred to as SUPL Location Platform (SLP). An LPP extension (LPPe) is also defined by OMA and may be used to extend the LPP signaling to provide more extended position reports or provide more assistance data to better support measurement of a certain method or to support more methods and RATs. Other extensions may potentially be supported by LPP in the future.

A high-level positioning architecture defined in the current standard is illustrated in Figure 4, where the LCS target is a user terminal, and the LCS server is an E-SMLC (Evolved Serving Mobile Location Centre (eSMLC) or an SLP (SUPL Location Platform). A Gateway Mobile Location Center (GMLC) is also shown but is not involved in the positioning. As shown in Figure 4, the control plane positioning protocols with E-SMLC as the terminating point are shown in dashed bold lines, and the user plane positioning protocol is shown in solid bold lines. SLP may comprise two components, SPC *(*SUPL positioning center*)* and SLC (SUPL Location Centre), which may also reside in different nodes. In an example implementation, SPC has a proprietary interface with E-SMLC, and Llp interface with SLC, and the SLC part of SLP communicates with the P-GW (Packet Data Network (PDN) Gateway) and external LCS Client.

Additional positioning architecture elements may also be deployed to further enhance performance of specific positioning methods. For example, deploying radio beacons is a cost-efficient solution which may significantly improve positioning performance indoors and also outdoors by allowing more accurate positioning, for example, with proximity location techniques.

The described protocols are so far defined to support mainly DL positioning.

UL positioning

The architecture for UL positioning, or network-based positioning, is currently being discussed in 3GPP. It is assumed that Uplink-Time Difference of Arriva (UTDOA) measurements are being performed by Location Measurement Units (LMUs), though measurements by BSs 25 are not precluded, and the measurements are based on Sounding Reference Signals (SRS). The following three approaches for communications between the positioning node and LMU are currently being discussed:

- LPPa-based for both BS-integrated and standalone LMUs,
- Transparent overlay for both BS-integrated and standalone LMUs using new interface (transparent to BS 25; the interface may be called "SLm") between E-SMLC and LMUs,
- Hybrid: LPPa-based for BS-integrated LMUs and Transparent overlay for standalone LMUs.
- Independently of the three approaches above, LPPa is likely to be enhanced for communications between BS 25 and E-SMLC necessary to support UTDOA (e.g., related to configuring SRS to enable UTDOA measurements).

Positioning result

A positioning result is a result of processing obtained measurements, including cell IDs, power levels, received signal strengths, etc., and it may be exchanged among nodes in one of the pre-defined formats. The signaled positioning result is represented in a pre-defined format corresponding to one of the seven Geographical Area Description (GAD) shapes.

The positioning result may be signaled between:

- LCS target and LCS server, e.g., over LPP protocol,
- Positioning servers (e.g., E-SMLC and SLP), over standardized or proprietary interfaces,
- Positioning server and other network nodes (e.g., E-SMLC and MME/MSC/GMLC/O&M(Operations and Management node)/SON),
- Positioning node and LCS client (e.g., between E-SMLC and Public Safety Answering Point (PSAP), or between SLP and External LCS client or between E-SMLC and user terminal).

LTE positioning methods

Cell ID and E-CID

Given the cell ID (CID) of the serving cell, the user terminal position is associated with the cell coverage area which can be described, for example, by a pre-stored polygon, where cell boundary is modeled by the set of non-intersecting polygon segments connecting all the corners.

Enhanced CID (E-CID) methods exploit four sources of position information: the CID and the corresponding geographical description of the serving cell, the round trip time (RTT) with respect to the serving cell (measured, e.g., by means of timing advance (TA) and/or receive-transmit time difference measured at either user terminal and base station (BS) side), the CIDs, and the corresponding signal measurements of the cells (up to 32 cells in LTE, including the serving cell), as well as angle-of-arrival (AoA) measurements. The three most common E-CID techniques include: CID+RTT, CID + signal strength and AoA + RTT. The positioning result of CID + RTT is typically an ellipsoid arc describing the intersection between a polygon and circle corresponding to RTT. A typical result format of the signal-strength based E-CID positioning is a polygon since the signal strength is subject, e.g., to fading effects, and therefore often does not scale exactly with the distance. A typical result of AoA + RTT positioning is an ellipsoid arc which is an intersection of a sector limited by AoA measurements and a circle from the RTT-like measurements.

Fingerprinting positioning

A more promising approach is provided by so called fingerprinting positioning.

Fingerprinting positioning algorithms operate by creating a radio fingerprint for each point of a fine coordinate grid that covers the Radio Access Network (RAN). The fingerprint may, e.g., consist of:

- The cell IDs that are detected by the terminal, in each grid point.

- Quantized path loss or signal strength measurements, with respect to multiple BSs 25, performed by the terminal, in each grid point. Note, an associated ID of the BS 25 may also be needed.
- Quantized TA, in each grid point (an associated ID of the BS 25 may also be needed).
- Quantized AoA information.

Whenever a position request arrives to the positioning method, a radio fingerprint is first measured, after which the corresponding grid point is looked up and reported. This process requires that the point is unique.

The database of fingerprinted positions can be generated in several ways. A first alternative would be to perform an extensive surveying operation that performs fingerprinting radio measurements repeatedly for all coordinate grid points of the RAN. The disadvantages of this approach include:

- The surveying required becomes substantial also for small cellular networks.
- The radio fingerprints are in some instants (e.g. signal strength and path loss) sensitive to the orientation of the terminal, a fact that is particularly troublesome for handheld terminals. For fine grids, the accuracies of the finger-printed positions may become highly uncertain. This uncertainty is seldom accounted for in the accuracy of the reported geographical result, thereby resulting in overoptimistic positioning reports.

OTDOA

The OTDOA positioning method makes use of the measured timing of downlink signals received from multiple radio nodes at the user terminal. With OTDOA, a user terminal measures the timing differences for downlink reference signals received from multiple distinct locations. For each (measured) neighbor cell, the user terminal measures the Reference Signal Time Difference (RSTD), which is the relative timing difference between neighbor cell and the reference cell. The user terminal position estimate is then found as the intersection of hyperbolas corresponding to the measured RSTDs. At least three measurements from geographically dispersed base stations with a good geometry are needed to solve for two coordinates of the user terminal and the receiver clock bias. In order to solve for position, precise knowledge of the transmitter locations and transmit timing offset is needed.

To enable positioning in LTE and facilitate positioning measurements of a proper quality and for a sufficient number of distinct locations, new physical signals, referred to as positioning reference signals (PRSs), dedicated to positioning have been introduced and low-interference positioning subframes have been specified in 3GPP (see, 3GPP TS 36.211). It will be appreciated, however, that OTDOA is not limited to PRS only and may be performed on other signals as well, e.g., CRS.

UTDOA

The uplink positioning makes use of the signals transmitted from user terminal. The timing of uplink signals is measured at multiple locations by radio nodes, e.g., by Location Measurement Units (LMUs) or BSs 25. The radio node measures the timing of the received signals using assistance data received from the positioning node, and the resulting measurements are used to estimate the location of the user terminal. Position calculation is similar to that with OTDOA.

GNSS and A-GNSS

Global Navigation Satellite System (GNSS) is a generic name for satellite-based positioning systems with global coverage. Examples of GNSS systems include the US Global Positioning System (GPS), the European Galileo, the Russian Glonass, and the Chinese Compass. GNSS positioning requires GNSS-capable receivers. With Assisted GNSS (A-GNSS), the receivers receive the assistance data from the network. The positioning calculation is based on multi-lateration with TOA-like measurements.

AECID positioning

Adaptive Enhanced Cell ID (AECID) is a positioning technology that refines the basic fingerprinting positioning method in a variety of ways. The AECID positioning method is based on the idea that high precision positioning measurements, e.g., A-GPS measurements or OTDOA measurements, can be seen as points that belong to regions where certain cellular radio propagation conditions persist. In its simplest form, A-GPS measurements that are performed at the same time as a certain cell ID is valid represent A-GPS measurements that fall within a specific cell of a cellular system. The AECID positioning method recognizes this and introduces a tagging of high precision measurements according to certain criteria, e.g., including:

- The cell IDs that are detected by the user terminal that performs the high precision position measurement.
- The measured angle of arrival (AoA).
- Quantized path loss or signal strength measurements, with respect to multiple RBSs, performed by the user terminal that performs the high precision position measurement.
- Quantized RTT in WCDMA or TA in LTE.

It is important to note that the tag consists of a vector of indices, each index taking an enumerable number of discrete values. Continuous variables used for tagging, like path loss, hence need to be quantized. Recently, it has become known that prior art for this first step of AECID positioning may exist.

The second step of the AECID positioning method is to collect all high precision positioning measurements that have the same tag in separate high precision measurement clusters, and to perform further processing of said cluster in order to refine it. It is clear that each such cluster consists of high precision position measurements collected from a region with similar radio conditions - hence the measurements are normally from the same well defined geographical region. More specifically, said geographical region is normally substantially smaller than the extension of a cell of the cellular system.

In a third step of the AECID positioning method, a polygon that represents the geographical extension of a cluster is computed, for each stored high precision position measurement cluster. The two most pronounced properties of the algorithm include:

- The area of the polygon is minimized (and hence accuracy maximized).
- The probability that the user terminal is within the polygon (the confidence) is precisely known (e.g., it is set as a constraint in the algorithm).

So far, steps toward the creation of a tagged database of polygons has been described.

An AECID position is now easily determined by a first determination of the persisting tag. This is performed by looking up cell IDs, by performing auxiliary measurements and by looking up auxiliary connection information, as described above. The polygon corresponding to the determined tag is then looked up in the tagged database of polygons, followed by reporting.

Closeness Positioning - Overview

The present disclosure provides low complexity methods for determining the closeness of neighbor cells to a user terminal. These methods are referred to as herein as closeness positioning. The closeness positioning techniques may be used, for example, to select neighbor cells near the user terminal on which to perform neighbor cell measurements. Thus, the neighbor cell measurements can be limited to the neighbor cells that are closest by the user terminal. By measuring less than all the neighboring cells, the signaling load on the network and user terminal measurement load will be decreased.

The closeness positioning techniques described herein have two main aspects. One aspect of closeness positioning comprises techniques implemented by a user terminal and a closeness determination node to build a closeness database. The closeness database stores closeness fingerprints and associated closeness indicators that may be used at a later time to determine the closeness of a user terminal to one or more cells in a network.

The second aspect of the closeness positioning techniques comprises procedures for determining the closeness of a user terminal to one or more cells in a network based on fingerprint measurements reported by the user terminal. The closeness determination node compares the set of fingerprint measurements provided by the user terminal to the closeness fingerprints stored in the closeness database. Based on the comparison, the closeness database generates a list of neighbor cells that are close to the user terminal.

A closeness determination node is provided to implement the closeness database build-up and closeness determination functions. The closeness determination node is typically a network node other than the positioning node, although a positioning node could also function as the closeness determination node. The consequence is that new signaling techniques are needed. The closeness determination node may, in some embodiments, be same as the network node that performs mobility management, i.e., the MME. The closeness determination node could also be a BS 25 or other radio access node. In some embodiments, the closeness determination node may be a stand-alone network node. In other embodiments, the closeness determination node could be distributed between two or more network nodes. The database build-up of procedures and closeness determination procedures are described in more detail below.

Closeness Database Build-up

The closeness database build-up procedures can be divided into four main phases as follows:

- Fingerprint Measurement
- Closeness Indicator Association
- Closeness Fingerprint Generation
- Database Creation/Update

The fingerprint measurement phase of the database build-up comprises the collection of fingerprint measurements. Fingerprint measurements are measurements that are used for fingerprint generation. Fingerprint measurements may be performed by a user terminal and reported to a base station or closeness determination node. In one embodiment, the user terminal sends the measurements to the serving BS 25 or closeness determination node in an RRC measurement report. Examples of fingerprint measurements performed by a user terminal include the serving cell ID, neighbor cell IDs, received signal strength measurements of neighbor cells, path loss to neighbor cells, timing advance (in LTE), round trip time (in LTE), and angle-of-arrival (in LTE). Also, fingerprint measurements by be performed by network nodes, such as a serving base station, neighbor base station, or other radio node. Examples of fingerprint measurements performed by a network node include timing advance (in LTE), round-trip time (in LTE), angle-of-arrival (in LTE), and uplink radio condition (e.g., determined via channel sounding).

The fingerprint measurements may comprise measurements associated with multiple user terminals as well as measurements associated with the same user terminal at different time instants.

The second phase of the database build-up procedure is the closeness indicator association phase. During this phase, one or more closeness indicators are associated with each fingerprint measurement. The closeness indicator is an indicator that indicates a degree of closeness of the user terminal reporting the fingerprint measurement to a particular cell. A position estimate, such as a GPS estimate, may be used to determine the location of the user terminal for closeness determination. Also, a location dependent radio procedures may be used to determine closeness. For example, the user terminal performing fingerprint measurements may be requested to search for a specific cell or cells. If one of the specified cells is detected by the user terminal, then the cell is determined to be close.

In one exemplary embodiment, a high precision position measurement associated with a user terminal is used for closeness estimation. In this case, the high precision position estimate may be generated by the user terminal, or may be generated by the network using known positioning techniques. For example, the high precision position estimate may comprise one of a standalone GPS position, an A-GPS position, an A-GNSS position, an OTDOA position (in LTE), or a U-TDOA position. In some embodiments, the high precision position estimate may be associated with fingerprint measurements previously reported to the BS 25 by the user terminal. Such association can be based on measurement time information, for example, by associating the fingerprint measurements closest in time, or fingerprint measurements interpolated from fingerprint measurements at time instants before and/or after the time of the high precision position measurement.

The closeness determination node may use the high precision position estimates to determine the closeness of the user terminals reporting the fingerprint measurements to one or more cells. In one exemplary embodiment, the closeness determination node computes a distance of each user terminal to the cell or cells of interest and converts the computed distances into a binary closeness indicator by comparing the computed distances to a threshold. To determine the relevant distances, the closeness determination node retrieves information about the location of the antennas or signaling points for the serving cell and neighbor cells in the vicinity of the user terminal. The location information is then used to compute the distances between user terminal and signaling points. The closeness indicators are then associated with the fingerprint measurements reported by the user terminals. In other embodiments, the computed distance may be used as a closeness indicator and associated with the fingerprint measurement.

In some embodiments, the fingerprint measurements may be grouped into measurement clusters based on the similarity of the measurements. That is, the fingerprint measurements forming the cluster should contain measurement components that are the same. It may be assumed that similar fingerprint measurements were collected from a region with similar radio conditions - hence the fingerprint measurements are probably from the same well defined geographical region. Coarse quantization may be applied to some measurement components before forming the fingerprint measurements. In one embodiment, the measurement clusters are formed from fingerprint measurements or quantized fingerprint measurements that are identical.

The measurement clusters may be processed by the closeness determination node to determine a closeness indicator applicable to each fingerprint measurement in the cluster. More particularly, a distance to a particular cell may be associated with each fingerprint measurement in the cluster. The calculated distances for the cluster may then be used for estimating closeness to the cell. As one example, the mean value of the distances in the cluster may be used for estimating closeness to a cell. That is, the mean value of the distances in the cluster may be compared to a threshold to generate a closeness indicator for the cluster. The closeness indicator for the cluster may be associated with each fingerprint measurement in the cluster.

It should be recognized that many statistical descriptions can be computed from a cluster of measurements. Potential candidates include:

- The complete probability distribution function (pdf) of the distances of the cluster approximated as a histogram, or by curve fitting.
- The complete cumulative probability distribution function (cdf) of the distances of the cluster approximated as a histogram, or by curve fitting.
- The mean value of the distances of the cluster.
- The median value of the distances of the cluster.
- One or more percentiles of the distances of the cluster.

Any of these statistical descriptions may be used for estimating closeness to a particular cell for purposes of generating a closeness indicator. More particularly, a thresholding operation may be applied to a statistical description of a cluster to generate the closeness indicator. The thresholding operation may operate only on a statistical description of one of the clusters corresponding to a cell. In this case the threshold may be absolute. Alternatively, the thresholding operation may operate on statistical descriptions of multiple clusters, each cluster corresponding to distances between the user terminal and one cell. In this case the threshold can use relative measures, e.g. to always return a predetermined number of the closest cells. The concept of relative thresholding and absolute thresholding can also be combined.

It should also be recognized that each fingerprint measurement may be associated with multiple closeness indicators, each of which indicates closeness to a particular cell.

In situations high precision position estimates are not be available for estimating closeness to a particular cell, the determination of the closeness indicator may be based on location dependent radio procedures, referred to herein as validation procedures. The basic idea is that a cell “visible” to the user terminal is close. For example, a cell may be determined to be close if the user terminal is able to receive signals from the cell, or if the BS 25 associated with the cell is able to receive signals from the user terminal. Validation procedures may be based on ordinary mobility procedures, on existing closeness estimation procedures, randomization, or other radio procedures.

When validation procedures are used for generating the closeness indicator, the closeness determination node may request the serving BS 25 to execute the validation procedure. Examples of validation procedures are as follows:

1) The BS 25 instructs the user terminal to include a first set of cells for which closeness estimation is considered in measurement reporting. The explicit inclusion of the first set of cells is useful in situations where the first set of cells would not otherwise be included in the measurement report. An example of this situation is when cells are blacklisted. The instruction from the BS 25 overrides or removes the blacklisting of the cells. The cell may be considered close if it is included in the measurement report from the user terminal and not close if it is not included. Alternatively, where the cell is included in the measurement report, it may be considered close only where the signal strength measurement meets a threshold.
2) In another example, the BS 25 may instruct the user terminal to measure cells on a different frequency and/or using a different radio access technology. As in the previous example, a cell may be considered close if it is included in the measurement report from the user terminal and not close if it is not included. Alternatively, when a cell is included in the measurement report, it may be considered close only when the reported signal strength measurement meets a threshold.
3) As another example, the serving BS 25 may instruct the user terminal to transmit a specific uplink waveform or signal to be detected by neighboring cells. The serving BS 25 may request the neighboring BSs 25 to listen for the transmission from the user terminal and report whether the transmission is detected. A cell detecting the uplink transmission is considered close. A cell that does not detect the uplink transmission is considered not close.

In other embodiments of the invention, the closeness estimation may be based on signal strength measurements. For example, where the set of fingerprint measurements provided by the user terminal include signal strength measurements for one or more cells, the closeness of the cells may be determined depending on the signal strength measurements. A cell may be considered close if the reported signal strength measurement associated with the cell meets a threshold. A cell is considered not close if the reported signal strength measurement associated with the cell does not meet the threshold.

The third phase of the database build-up procedure is fingerprint generation. During the fingerprint generation phase, the closeness determination node generates a closeness fingerprint from one or more sets of fingerprint measurements selected based on the closeness indicators and/or measurement components. While a closeness fingerprint may be generated from a single set of fingerprint measurements, it is generally desirable to generate closeness fingerprints from two or more sets of fingerprint measurements having the same closeness indicators. In one embodiment, the closeness fingerprint is generated from a cluster of fingerprint measurements. Some components of the fingerprint measurements may be subject to quantization. The closeness indicator for the closeness fingerprint is typically selected based on statistical descriptions of the cluster as outlined above. The closeness fingerprint and associated closeness indicators may then be stored in a closeness database. The closeness fingerprint may include one or more components including the serving cell ID, one or more neighbor cell IDs, received signal strength measurements of one or more neighbor cells, path loss to neighbor cells, timing advance (in LTE), round trip time (in LTE), and angle-of-arrival (in LTE).

Often, the resolution of the fingerprint measurements is too fine, resulting in overlapping regions between neighboring fingerprints. The closeness fingerprint generation thus may be performed by the following steps:

- Quantization of measurement components in the fingerprint measurements.
- Merging the quantized fingerprint measurement to form the closeness fingerprint.

In general the quantization should reflect the consistent accuracy of the corresponding measurement component that is being quantized. For example, TA measurements in LTE may be accurate to the 50-100 m range in the field, whereas the resolution is close to 10 m. Hence the TA measurements could preferably be quantized to somewhere close to the 50-100 m range in such a situation. Some measurement components, such as cell ID may not be subject to quantization.

The components of the fingerprint may be hierarchically organized with the information most likely available at the top. In case measurement components are lacking, then a truncation of the closeness fingerprint can return a statistical description of closeness higher up in the hierarchy, with less accuracy, but keeping the system operational. A suitable hierarchy could, e.g., have the own cell ID at the top level, neighbor cell IDs at the second level, TA at the third level, and so on.

The final phase of the database build-up is the closeness database creation and/or update. After generating the closeness fingerprint, the closeness fingerprint may be stored in a closeness database along with other information, such as the closeness indicator used in the selection of the fingerprint measurements. The closeness database may also be an extension of the Neighbor Relationship Table (NRT) defined in TS36.300. Namely, for each cell in the NRT for which a neighbor relationship has been created with the serving cell, the information according to which closeness is established, e.g., the closeness fingerprint, may be stored.

Closeness Determination

The closeness determination uses a closeness fingerprint obtained from fingerprint measurements performed by one or more user terminal. The stored closeness fingerprints may be used, for example, to aid neighbor cell measurements. More particularly, the stored closeness fingerprints may be used to determine which cells are close to the user terminal and thus should be included in the neighbor cell measurements. It should be recognized that other situations may occur where it is desirable to determine the closeness of a user terminal to a cell.

To determine the cells close to a user terminal, it is enough for the user terminal to perform fingerprint measurements and report the fingerprint measurements to the serving BS 25 or closeness determination. This serving BS 25 or closeness determination node may then look up the neighbor cells that are "close" by comparing the reported fingerprint measurements to the closeness fingerprints stored in the closeness database. If a matching closeness fingerprint is found, the closeness indicators associated with the matching closeness fingerprint, together with the associated cell IDs, may be sent to the user terminal. Alternatively, the serving BS 25 or closeness determination node can compute the close cells and transmit a list of the close cells back to the user terminal. In the first case, the user terminal needs to determine the close cells. The advantage with sending also potentially close, but not close cells to the user terminal is that the user terminal may use further information to refine its view on which cells that are close.

In one embodiment, the serving BS 25 may request the user terminal to perform fingerprint measurements and send a lookup request including the fingerprint measurements received from the user terminal to the closeness determination node, which performs the lookup. The serving BS 25 may receive a lookup response from the closeness determination node including a list of close neighbor cells. Alternatively, the serving BS 25 may store the closeness database and perform the lookup. In either case, the serving BS 25 may configure the user terminal to perform neighbor cell measurements on the neighbor cells determined to be close to the user terminal. In one embodiment, the user terminal is configured using RRC signalling, such as the "measSubframeCellList" parameter. More particularly, the serving BS 25 may transmit a list of close cells to the user terminal that provided the measurements and/or a list of neighbor cells with their corresponding closeness indicators.

In another embodiment, the user terminal sends the fingerprint measurements to the closeness determination node using RRC signaling. The closeness determination node performs a database lookup to find matching closeness fingerprints. In one embodiment, the closeness determination node sends the user terminal a list of closeness indicators and associated cell IDs for the matching closeness fingerprints. The user terminal may then determine which cells are close based on the received closeness indicators. In other embodiments, the closeness determination node may compute a list and transmit the list to the user terminal via RRC signaling, e.g., in the "measSubframeCellList" parameter, to configure the user terminal.

The database lookup is performed by comparing the fingerprint measurements received from the user terminal to the closeness fingerprints in the closeness database. The fingerprint measurements may be quantized prior to performing the lookup. In general, the user terminal is considered close to a cell if the fingerprint measurements received from the user terminal matches the closeness fingerprint associated with the cell. In one embodiment, the received fingerprint measurement is compared component by component to the stored closeness fingerprint for a cell to determine the closeness to the cell. For each component, a matching criterion is defined. The user terminal is considered close if the received fingerprint measurement matches all of the components of the closeness fingerprint. Alternatively, the user terminal may be considered close if the received fingerprint measurement matches a predetermined number of the components of the closeness fingerprint.

Denoting a fingerprint measurement (or a relative fingerprint measurement) to be tested for closeness *m*, with components $m_1, \ldots m_N$. and a closeness fingerprint *r*, with components $r_1, \ldots r_N$., the user terminal is considered close if:

$$| m_i - r_i| <= d_i, \text{ for all, or some } I, \text{ where } d_i \text{ is a parameter}$$

Alternatively, the user terminal is considered close if:

$$| m_i - r_i|^c <= d_i, \text{ for all, or some } I, \text{ where } d_i \text{ and c are parameters}$$

In some embodiments, closeness may be determined using a weighted sum as follows:

$$D \geq \sum_{i=1}^{N} w_i |m_i - r_i|^c$$

In some embodiments, the close and non-close fingerprint measurements can be manipulated so that the manipulated fingerprint measurements are well separated. Denote the random variables corresponding to close fingerprint measurement vectors as *c*, and the non-close fingerprint measurement vectors as *n* with a corresponding mean and covariance. The projection of these vectors to subspaces in different ways will make the separation between close and non-close radio measurements different. Lindgren, Spångeus ”A novel feature extraction algorithm”, IEEE Sensors Journal, Vol 4, No 5, Oct 2004 describes asymmetric class projection suitable to find such projections for gas sensors.

The mechanism to assess closeness may be configured based on pre-determined thresholds and other parameters. In one embodiment, an Operation and Management (OaM) system configures the network node implementing the closeness determination function with such parameters. Furthermore, the reporting criterions and performance measurements may also be defined. The network node collects statistics of the performance, for example counters of closeness estimation success and failures, number of radio measurements considered as close and non-close, etc. Note that closeness estimation success and failure can be determined via the validation step described above. An exemplary OaM system is illustrated in Figure 2.

Closeness Positioning Example

Figures 5 and 6 illustrate an exemplary scenario that will be used to explain closeness database build-up and closeness determination. The network environment illustrates in Figures 5 and 6 comprises four cells (denoted Cell1-Cell4) served by four BSs (denoted BS1-BS4) and four user terminals (denoted UE1-UE4). BS1 is the serving BS 25 for UE1 – UE4. In this example, UE1 – UE4 report fingerprint measurements to BS1, which communicates with the closeness determination node (not shown).

BS1 receives fingerprint measurements from each one of UE1 –UE4 as shown in Table 1 below.

Fingerprint Measurement No	Fingerprint Measurement
1	RSRP(Cell ID 1)=-80 dBm, RSRP(Cell ID 2)=-95 dBm, Dist(Cell ID 1) = 54m
2	RSRP(Cell ID 1)=-87 dBm. RSRP(Cell ID 2)=-96 dBm, Dist(Cell ID 1) = 46m
3	RSRP(Cell ID 1)=-83 dBm, RSRP(Cell ID 2)=-94 dBm, RSRP(Cell ID 3)=-99 dBm, Dist(Cell ID 1) = 60m
4	RSRP(Cell ID 1)=-80 dBm, Dist(Cell ID 1) = 32m

The fingerprint measurements comprise the cell ID and RSRP measurements with respect to the serving cell (Cell1) and two neighbor cells (Cell 2 and Cell 3), and the distances of UE1-UE4 to the serving cell (Cell 1). Though not shown in Table 1, it is assumed that theUE1-UE4 have also reported a high precision location to BS1. The fingerprint measurements and high precision locations are provided by BS1 to the closeness determination node.

The closeness determination node may use the high precision locations reported by UE1-UE4 to determine the closeness of UE1-UE4 to Cell4 and associate a closeness indicator to each set of fingerprint measurements. In one exemplary embodiment, the closeness indicator is a binary indicator that indicates close or not close. The closeness determination node computes a distance of each user terminal to the cell of interest (e.g., Cell4) and converts the computed distance into a binary closeness indicator. The closeness indicator is then associated with the fingerprint measurement reported by the user terminal. In other embodiments, the computed distance may be used as a closeness indicator and associated with the fingerprint measurement.

In the example shown in Figures 5 and 6, the closeness determination node determines the distances of UE1-UE4, denoted respectively as D1-D4, to Cell4. It is assumed that the geographic location of Cell4 is known to or can be determined by the closeness determination node. Thus, distances D1-D4 can be computed from the reported locations of UE1-UE4 and the location of Cell4. To determine the closeness indicator for the fingerprint measurements, the closeness determination node may compare the computed distances D1-D4 to a threshold. If the computed distance is less than or equal to the threshold, the UE is determined to be close to the cell. Otherwise, the user terminal is determined to be not close to the cell. In this example, UE1-UE3 are determined to be close to Cell4 and UE4 is determined to be not close to Cell4. Once the closeness of the reporting user terminal is determined, a binary closeness indicator is associated with each fingerprint measurements.

The fingerprint measurements made by the user terminals may be stored in a measurement database along with the corresponding closeness indicators. Although only one closeness indicator with respect to Cell4 is determined in this example for each fingerprint measurement, it should be recognized that multiple closeness indicators can be associated with the same fingerprint measurement.

The fingerprint measurements stored in the fingerprint measurement database may be used to generate closeness fingerprints and to build a closeness database including the closeness fingerprints and corresponding closeness indicator. Generally, a group of fingerprint measurements with the same closeness indicators, or very similar closeness indicators, can be used to generate a closeness fingerprint. Referring to the example shown in Figures 5 and 6, the fingerprint measurements from UE1-UE3 are deemed to be close to Cell4 and may be used to generate a closeness fingerprint for Cell4. The closeness fingerprint is generated from common components in the selected fingerprint measurement sets. As shown in this example, each set of fingerprint measurements includes the RSRP of Cell1 and Cell 2, but not of Cell 3. The closeness fingerprint for this example may be generated as follows:

- If only the presence of a cell in the fingerprint measurement is considered informative, the closeness fingerprint is:

  Cell_ID1; Cell_ID2.

- If the signal strength measurements are considered, the closeness fingerprint may also include the average of the signal strength measurements. In the example given, the closeness fingerprint would be:

  Cell_ID1, RSRP = -90 dBm; Cell_ID2, RSRP = -95 dBm

- The closeness fingerprint can be based on relative values for neighbor cells relative to the serving cell value. In the example given, the closeness fingerprint would be:

  Cell_ID1, RSRP = -90 dBm; Cell_ID2, RSRP_rel1 = -5 dB

The closeness fingerprints as described above may be used for identifying cells that are close to a user terminal. When it is desired to identify cells that are close to the user terminal, the user terminal can be instructed to perform fingerprint measurements and report the fingerprint measurements to the serving BS 25. The received fingerprint measurements are compared to the closeness fingerprint on a component by component basis. A cell is considered close when the fingerprint measurement reported by the user terminal matches the stored closeness fingerprint associated with the cell.

In the example given above, where only the presence of the cell is considered, the fingerprint measured is considered a match if the fingerprint measurement includes all of the cells in the closeness fingerprint. For the example given above, a match is declared when the fingerprint measurements includes both Cell1 and Cell2. This matching criterion is met by the fingerprint measurements for UE1-UE3, but not UE4.

In the case where signal strength measurements are considered, the fingerprint measurement is considered close where the signal strength measurements for both Cell 1 and Cell 2 meet a predetermined criterion. In the example given above, the fingerprint measurement may be declared a match if:

$$(-94 <= \text{Cell 1 RSRP} < -86\ \text{dBm})\ \&\ (-93 <= \text{Cell 2 RSRP} < -87\ \text{dBm})$$

If the signal strength measurements meet the criteria, the cell is considered close. Otherwise, the cell is determined to be not close. The matching criterion is met by the fingerprint measurements for UE1-UE3, but not UE4.

Closeness fingerprint quantization is also applicable in the examples given above.

Signaling Operations

In one exemplary embodiment, the signaling operations include:

- Signaling of user terminal high precision position from the user terminal to the closeness determination node. This can be a positioning of opportunity event or requested by the closeness node.
- Signaling of fingerprint measurements (for fingerprint computation) from the user terminal to the closeness determination node. This can be a positioning of opportunity event or requested by the closeness node.
- Signaling from the closeness determination node to the user terminal, may comprise either a list of close cells, or a list of cells and associated closeness indicators.

Fig. 7 illustrates a method 100 performed by a closeness determination node for building a closeness database. The closeness determination node receives fingerprint measurements from each of one or more user terminals (block 105). The fingerprint measurements may comprise one or more components. After receiving the fingerprint measurements, the closeness determination node associates a closeness indicator with each set of fingerprint measurements (block 110). As described above, the closeness indicator may be determined based on high precision position estimates, or based on validation procedures. The closeness determination node then generates a closeness fingerprint from subsets of the fingerprint measurements selected based on the closeness indicator (block 115). Finally, the closeness determination node stores the generated closeness fingerprint in a closeness database (block 120). Other information may be stored along with the closeness fingerprint, such as the closeness indictor.

Fig. 8 illustrates another exemplary method 150 implemented by a closeness determination node for determining cells within the network that are close to a user terminal. The closeness determination node receives a set of fingerprint measurements made by the user terminal on one or more cells (block 155). The closeness determination node compares the received fingerprint measurements to one or more closeness fingerprints stored in a closeness database (block 160). Based on the comparison of the fingerprint measurements with the stored closeness fingerprints, the closeness determination node generates a list of neighbor cells that are considered to be close to the user terminal (block 165). The closeness determination node sends the neighbors a list to the user terminal or to a BS 25 serving the user terminal (block 170).

Fig. 9 illustrates a method 200 implemented by a user terminal of making measurements on neighbor cells. The user terminal performs fingerprint measurements on one or more cells in the proximity of the user terminal (block 205). Those cells may include the user terminals own cell and one or more neighbor cells. The user terminal sends the fingerprint measurements to a serving BS 25 or to a closeness determination node (block 210). In response to the measurement report, the user terminal receives a neighbor cell list from the closeness determination node or serving BS 25 (block 215). The neighbor cell list contains the neighbor cells determined to be close to the user terminal based on the fingerprint measures provided by the user terminal. The user terminal may optionally store the neighbor cell list in memory (block 220). Subsequently, the user terminal performs cell measurements on the neighbor cells in the neighbor cell list.

Figure 10 illustrates the main functional elements of an exemplary user terminal 300 configured to carry out procedures described in this invention. The user terminal 300 comprises radio circuitry 310, processing circuits 320, and memory 330. The radio circuitry 310 enables the user terminal 300 to communicate with the serving BS 25 or BSs 25 in neighboring cells, and to receive signals on which measurements are performed. The processing circuit 320 processes signals transmitted and received by the user terminal and controls the operation of the user terminal 300. The processing circuit 320 may comprise one or more processors, hardware, firmware or a combination thereof. Memory 330 stores programs and data needed for operation as herein described. Stored information includes information about serving cell and neighbor cells, as well as configuration information signaled by the serving BS 25 or closeness determination node.

Figure 11 illustrates the main functional elements of an exemplary closeness determination node 400 configured to carry out procedures described in this invention. The closeness determination node 400 may be co-located with the serving BS 25, or it may be a different logical node connected to the serving BS 25, or it may be a different node not connected to the serving BS 25.

In one embodiment, the closeness determination node 400 comprises communication circuitry 410, processing circuits 420, and memory 430. The closeness determination node 400 may also optionally include radio circuitry 440. The communication circuitry 410 enables the closeness determination node 400 to communicate with the BSs 25 and other network nodes within the communication network. The communication circuitry 410 enables the closeness determination node 400 to receive measurement reports from the user terminal or serving BS 25 and other information relevant for closeness positioning. The communication circuitry 410 also enables the closeness determination node 400 to send RRC signaling and other configuration instructions to the BS 25 and/or user terminal to configure measurement reporting. The processing circuit 420 is configured or programmed to perform closeness database build-up and closeness determination as herein described. The processing circuit 420 may comprise one or more processors, hardware, firmware or a combination thereof. Memory 430 stores programs and data needed by the closeness determination node 400 for operation as herein described. The memory 430 is configured to store fingerprint measurements and other information reported by user terminals about served cell as well as neighbor cell. The memory 430 is also used to store the closeness database. The radio circuitry 440 may, in some embodiments be used to communicate with user terminals or other network nodes. Thus, the radio circuitry 440, when present, enables the closeness determination node to receive measurement reports from the user terminal, and to send RRC signaling to the user terminal to configure neighbor cell measurements.

CLAIMS

What is claimed is:

1. A method implemented by a network node in a wireless communication system, the method comprising:

receiving a set of fingerprint measurements from each of one or more user terminals;

generating a closeness indicator for each set of fingerprint measurements, said closeness indicator indicating a closeness of a corresponding one of the user terminals to a given access node;

generating a closeness fingerprint from one or more sets of said fingerprint measurements selected based on the closeness indicator; and

storing the closeness fingerprint and associated closeness indicator in a neighbor cell database.

2. The method of claim 1 wherein each set of fingerprint measurements comprises at least a cell ID.

3. The method of claim 2 wherein one or more of the sets of fingerprint measurements further comprises at least one of:

a received signal strength of a reference signal;

a path loss;

a timing advance;

a round trip time; and

a measured angle of arrival of a reference signal.

4. The method of claim 1 wherein generating a closeness indicator for each set of fingerprint measurements comprises, for each set of fingerprint measurement:

computing the distance between the corresponding user terminal and a signaling point;

generating the closeness indicator for the set of fingerprint measurements based on the distance.

5. The method of claim 4 wherein computing a distance between the user terminal and the signaling point comprises computing the distance between a location of the user equipment and the location of the signaling point.

6. The method of claim 4 wherein generating the closeness indicator for the set of fingerprint measurements based on the distance comprises generating the closeness indicator by comparing the distance to a threshold to determine closeness.

7. The method of claim 4 wherein generating the closeness indicator for the set of fingerprint measurements based on the distance comprises

determining a plurality of clusters of fingerprint measurements;

computing a statistical description of each of the clusters; and

generating a closeness indicator based on the statistical description of each of the clusters.

8. The method of claim 7 wherein computing a statistical description comprises computing a probability distribution function of the distances of the fingerprint measurements in each cluster; and wherein generating the closeness indicator based on the statistical description comprises generating the closeness indicator based on the probability distribution function.

9. The method of claim 7 wherein computing a statistical description comprises computing a mean value or median value of the distances of the fingerprint measurements in each cluster; and wherein generating the closeness indicator based on the statistical description comprises determining the closeness indicator based on the mean value or median value of the distances.

10. The method of claim 7 wherein computing a statistical description of the cluster comprises computing one or more percentiles of the distances of the fingerprint measurements in the cluster; and wherein generating the closeness indicator based on the statistical description comprises determining the closeness indicator based on the percentiles of the distances.

11. The method of any of claims 7-10 wherein each cluster comprises identical sets of fingerprint measurements.

12. The method of any of claims 7-11 further comprising quantizing one or more measurement components of the fingerprint measurements in each cluster.

13. The method of any of claims 7-12 wherein generating a closeness fingerprint from one or more sets of said fingerprint measurements selected based on the closeness indicator comprises generating a closeness fingerprint for each cluster of fingerprint measurements.

14. The method of claim 1 wherein generating a closeness indicator comprises:

instructing one or more user terminals to perform a measurement on one or more specified cells;

receiving measurement reports including the measurements from the user terminals; and

determining a closeness indicator based on the radio measurements.

15. The method of claim 14 wherein instructing one or more user terminals to perform a measurement on or more specified cells comprises instructing one or more user terminals to perform radio measurements for blacklisted cells.

16. The method of claim 14 wherein instructing one or more user terminals to perform a measurement on or more specified cells comprises instructing one or more user terminals to perform radio measurements for inter-frequency cells.

17. The method of claim 1 wherein generating a closeness indicator comprises:

instructing one or more user terminals to transmit a test signal;

instructing one or more neighboring access nodes to receive the test signals

receiving reports from the neighboring access nodes indicating whether the test signal was detected.

18. The method of claim 1 wherein generating a closeness fingerprint comprises:

selecting one or more sets of fingerprint measurements; and

generating a closeness fingerprint comprising one or more components from the selected sets of fingerprint measurements.

19. The method of claim 18 wherein generating a closeness fingerprint comprising one or more components from the selected sets of fingerprint measurements comprises:

identifying a cluster of fingerprint measurements; and

generating a closeness fingerprint from the cluster of fingerprint measurements.

20. The method of claim 18 or 19 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements comprises determining a set of one or more cell IDs from the fingerprint measurements to include in the closeness fingerprint.

21. The method of claim 19 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one signal strength measurement for each cell id to include in the closeness fingerprint.

22. The method of claim 19 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one timing advance for each cell id to include in the closeness fingerprint.

23. The method of claim 19 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one round trip time for each cell id to include in the closeness fingerprint.

24. The method of claim 19 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one time of arrival of a reference signal for each cell id to include in the closeness fingerprint.

25. The method of claim 17 or 18 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements comprises:

quantizing one or more of the components of the fingerprint measurements to obtain quantized fingerprint measurements.

26. The method of claim 25 wherein generating a closeness fingerprint from the selected sets of fingerprint measurements further comprises:

merging the quantized fingerprint measurements to obtain the closeness fingerprint.

27. The method of claim 1 further comprising hierarchically ranking components of the closeness fingerprint.

28. A method of determining the closeness of one or more neighbor cells to a user terminal, the method comprising:

receiving, from the user terminal, a set of fingerprint measurements corresponding to one or more cells;

comparing the received fingerprint measurements to one or more stored closeness fingerprints in a neighbor cell database; and

generating a list of neighbor cells based on the comparison of the fingerprint measurements with the stored closeness fingerprints.

29. The method of claim 28 wherein generating the list of neighbor cells comprises generating a list of neighbor cells that are deemed to be close to the user terminal based on closeness indicators associated with the closeness fingerprint.

30. The method of claim 29 further comprising sending the list of neighbor cells including the cell ID for neighbor cells deemed to be close to the user terminals.

31. The method of claim 28 wherein the list of neighbor cells includes corresponding closeness indicators.

32. The method of claim 31 further comprising sending the list of neighbor cells and corresponding closeness indicator to the user terminal.

33. A network node in a wireless communication system, the network node comprising:

a communication circuit for communication with other network nodes;

a processing circuit operatively connected to the communication circuit, the processing circuit being configured to:

receive a set of fingerprint measurements from each of one or more user terminals;

generate a closeness indicator for each set of fingerprint measurements, said closeness indicator indicating a closeness of a corresponding one of the user terminals to a given access node;

generate a closeness fingerprint from one or more sets of said fingerprint measurements selected based on the closeness indicator; and

store the closeness fingerprint and associated closeness indicator in a neighbor cell database.

34. The network node of claim 33 wherein each set of fingerprint measurements comprises at least a cell ID.

35. The network node of claim 34 wherein one or more of the sets of fingerprint measurements further comprises at least one of:

a received signal strength of a reference signal;

a path loss;

a timing advance;

a round trip time; and

a measured angle of arrival of a reference signal.

36. The network node of claim 33 wherein generating, by the processing circuit, a closeness indicator for each set of fingerprint measurements comprises, for each set of fingerprint measurement:

computing the distance between the corresponding user terminal and a signaling point;

generating the closeness indicator for the set of fingerprint measurements based on the distance.

37. The network node of claim 36 wherein computing, by the processing circuit, a distance between the user terminal and the signaling point comprises computing the distance between a location of the user equipment and the location of the signaling point.

38. The network node of claim 36 wherein generating, by the processing circuit, the closeness indicator for the set of fingerprint measurements based on the distance comprises generating the closeness indicator by comparing the distance to a threshold to determine closeness.

39. The network node of claim 36 wherein generating, by the processing circuit, the closeness indicator for the set of fingerprint measurements based on the distance comprises

determining a plurality of clusters of fingerprint measurements;

computing a statistical description of each of the clusters; and

generating a closeness indicator based on the statistical description of each of the clusters.

40. The network node of claim 39 wherein computing, by the processing circuit, a statistical description comprises computing a probability distribution function of the distances of the fingerprint measurements in each cluster; and wherein generating, by the processing circuit, the closeness indicator based on the statistical description comprises generating the closeness indicator based on the probability distribution function.

41. The network node of claim 39 wherein computing, by the processing circuit, a statistical description comprises computing a mean value or median value of the distances of the fingerprint measurements in each cluster; and wherein generating the closeness indicator based on the statistical description comprises determining the closeness indicator based on the mean value or median value of the distances.

42. The network node of claim 39 wherein computing, by the processing circuit, a statistical description of the cluster comprises computing one or more percentiles of the distances of the fingerprint measurements in the cluster; and wherein generating, by the processing circuit, the

closeness indicator based on the statistical description comprises determining the closeness indicator based on the percentiles of the distances.

43. The network node of any of claims 39-42 wherein each cluster comprises identical sets of fingerprint measurements.

44. The network node of any of claims 39-43 wherein the processing circuit is further configured to quantize one or more measurement components of the fingerprint measurements in each cluster.

45. The network node of any of claims 39-44 generating a closeness fingerprint from one or more sets of said fingerprint measurements selected based on the closeness indicator by the processing circuit comprises generating a closeness fingerprint for each cluster of fingerprint measurements.

46. The network node of claim 33 wherein generating, by the processing circuit, a closeness indicator comprises:

instructing one or more user terminals to perform a measurement on one or more specified cells;

receiving measurement reports including the measurements from the user terminals; and

determining a closeness indicator based on the radio measurements.

47. The network node of claim 46 wherein instructing, by the processing circuit, one or more user terminals to perform a measurement on or more specified cells comprises instructing one or more user terminals to perform radio measurements for blacklisted cells.

48. The network node of claim 46 wherein instructing, by the processing circuit, one or more user terminals to perform a measurement on or more specified cells comprises instructing one or more user terminals to perform radio measurements for inter-frequency cells.

49. The network node of claim 33 wherein generating, by the processing circuit, a closeness indicator comprises:

instructing one or more user terminals to transmit a test signal;

instructing one or more neighboring access nodes to receive the test signals

receiving reports from the neighboring access nodes indicating whether the test signal was detected.

50. The network node of claim 33 wherein generating, by the processing circuit, a closeness fingerprint comprises:

selecting one or more sets of fingerprint measurements; and

generating a closeness fingerprint comprising one or more components from the selected sets of fingerprint measurements.

51. The network node of claim 50 wherein generating, by the processing circuit, a closeness fingerprint comprising one or more components from the selected sets of fingerprint measurements comprises:

identifying a cluster of fingerprint measurements; and

generating a closeness fingerprint from the cluster of fingerprint measurements.

52. The network node of claim 50 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements comprises determining a set of one or more cell IDs from the fingerprint measurements to include in the closeness fingerprint.

53. The network node of claim 51 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one signal strength measurement for each cell id to include in the closeness fingerprint.

54. The network node of claim 52 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one timing advance for each cell id to include in the closeness fingerprint.

55. The network node of claim 52 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one round trip time for each cell id to include in the closeness fingerprint.

56. The network node of claim 52 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements further comprises determining at least one time of arrival of a reference signal for each cell id to include in the closeness fingerprint.

57. The network node of claim 52 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements comprises:

quantizing one or more of the components of the fingerprint measurements to obtain quantized fingerprint measurements.

58. The network node of claim 57 wherein generating, by the processing circuit, a closeness fingerprint from the selected sets of fingerprint measurements further comprises:

merging the quantized fingerprint measurements to obtain the closeness fingerprint.

59. The network node of claim 33 wherein the processing circuit is further configured to hierarchically rank components of the closeness fingerprint.

60. A network node of determining the closeness of one or more neighbor cells to a user terminal, the network node comprising:

a communication circuit for communication with other network nodes;

a processing circuit operatively connected to the communication circuit, the processing circuit being configured to:

receive, from the user terminal, a set of fingerprint measurements corresponding to one or more cells;

compare the received fingerprint measurements to one or more stored closeness fingerprints in a neighbor cell database; and

generate a list of neighbor cells based on the comparison of the fingerprint measurements with the stored closeness fingerprints.

61. The network node of claim 60 wherein generating, by the processing circuit, the list of neighbor cells comprises generating a list of neighbor cells that are deemed to be close to the user terminal based on closeness indicators associated with the closeness fingerprint.

62. The network node of claim 61 wherein the processing circuit is further configured to send the list of neighbor cells including the cell ID for neighbor cells deemed to be close to the user terminals.

63. The network node of claim 60 wherein the list of neighbor cells includes corresponding closeness indicators.

64. The network node of claim 63 wherein the processing circuit is further configured to send the list of neighbor cells and corresponding closeness indicator to the user terminal.

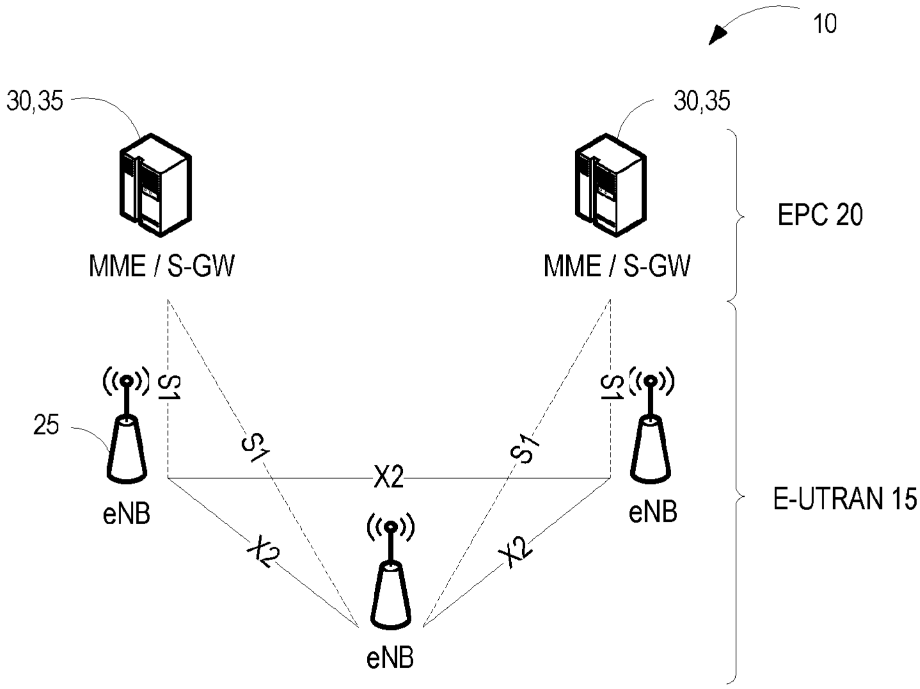
10
30,35
30,35
EPC 20
MME / S-GW
MME / S-GW
S1
S1
S1
S1
25
X2
E-UTRAN 15
eNB
eNB
X2
X2
eNB

FIG. 1

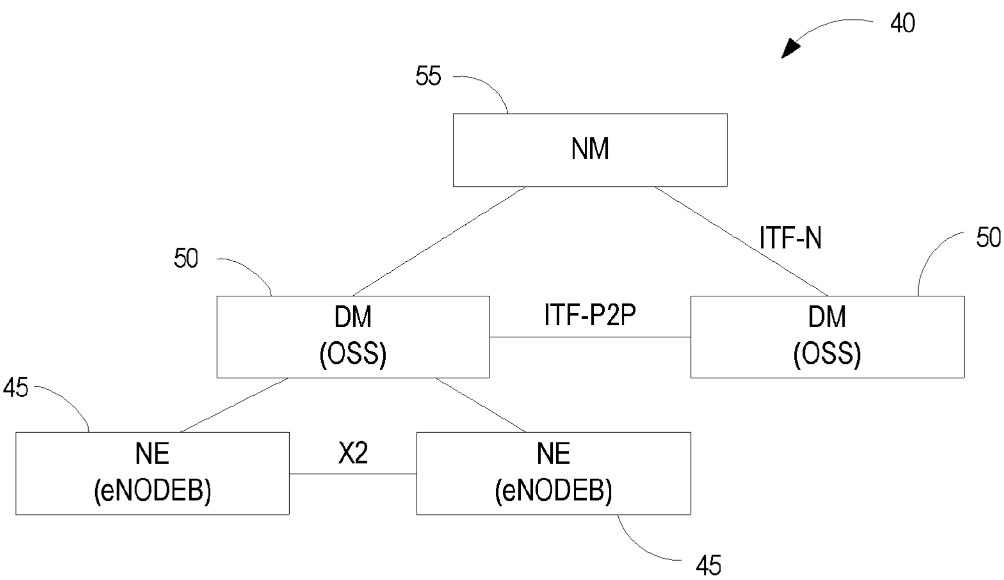
40
55
NM
ITF-N
50
50
DM
(OSS)
ITF-P2P
DM
(OSS)
45
NE
(eNODEB)
X2
NE
(eNODEB)
45

FIG. 2

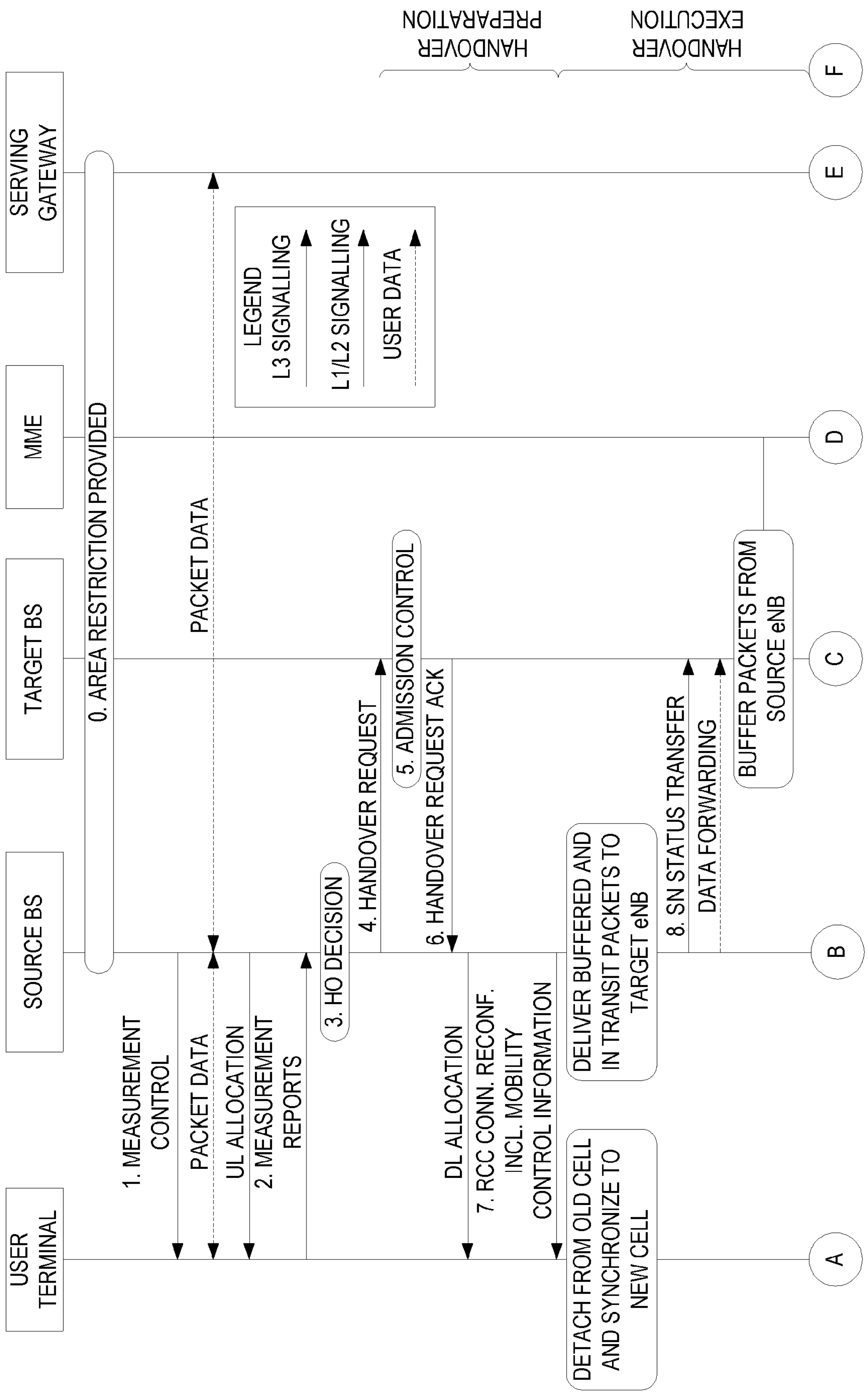
USER TERMINAL
SOURCE BS
TARGET BS
MME
SERVING GATEWAY
0. AREA RESTRICTION PROVIDED
PACKET DATA
LEGEND
L3 SIGNALLING
L1/L2 SIGNALLING
USER DATA
1. MEASUREMENT CONTROL
PACKET DATA
UL ALLOCATION
2. MEASUREMENT REPORTS
3. HO DECISION
4. HANDOVER REQUEST
5. ADMISSION CONTROL
6. HANDOVER REQUEST ACK
DL ALLOCATION
7. RCC CONN. RECONF. INCL. MOBILITY CONTROL INFORMATION
DETACH FROM OLD CELL AND SYNCHRONIZE TO NEW CELL
DELIVER BUFFERED AND IN TRANSIT PACKETS TO TARGET eNB
8. SN STATUS TRANSFER
DATA FORWARDING
BUFFER PACKETS FROM SOURCE eNB
HANDOVER PREPARATION
HANDOVER EXECUTION
A
B
C
D
E
F

FIG. 3A

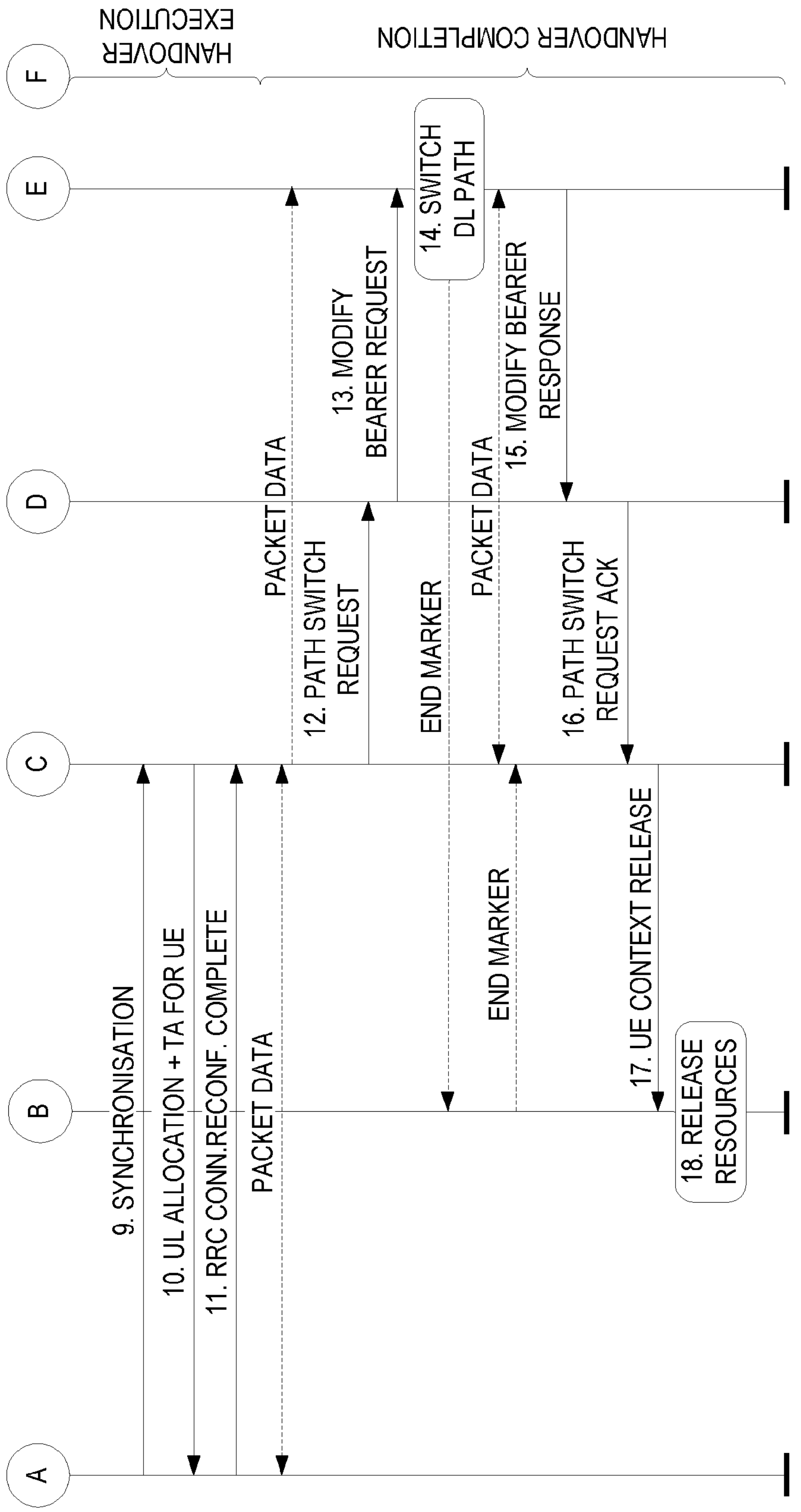
A
B
C
D
E
F
HANDOVER EXECUTION
HANDOVER COMPLETION
9. SYNCHRONISATION
10. UL ALLOCATION + TA FOR UE
11. RRC CONN.RECONF. COMPLETE
PACKET DATA
PACKET DATA
12. PATH SWITCH REQUEST
13. MODIFY BEARER REQUEST
14. SWITCH DL PATH
END MARKER
PACKET DATA
15. MODIFY BEARER RESPONSE
END MARKER
16. PATH SWITCH REQUEST ACK
17. UE CONTEXT RELEASE
18. RELEASE RESOURCES

FIG. 3B

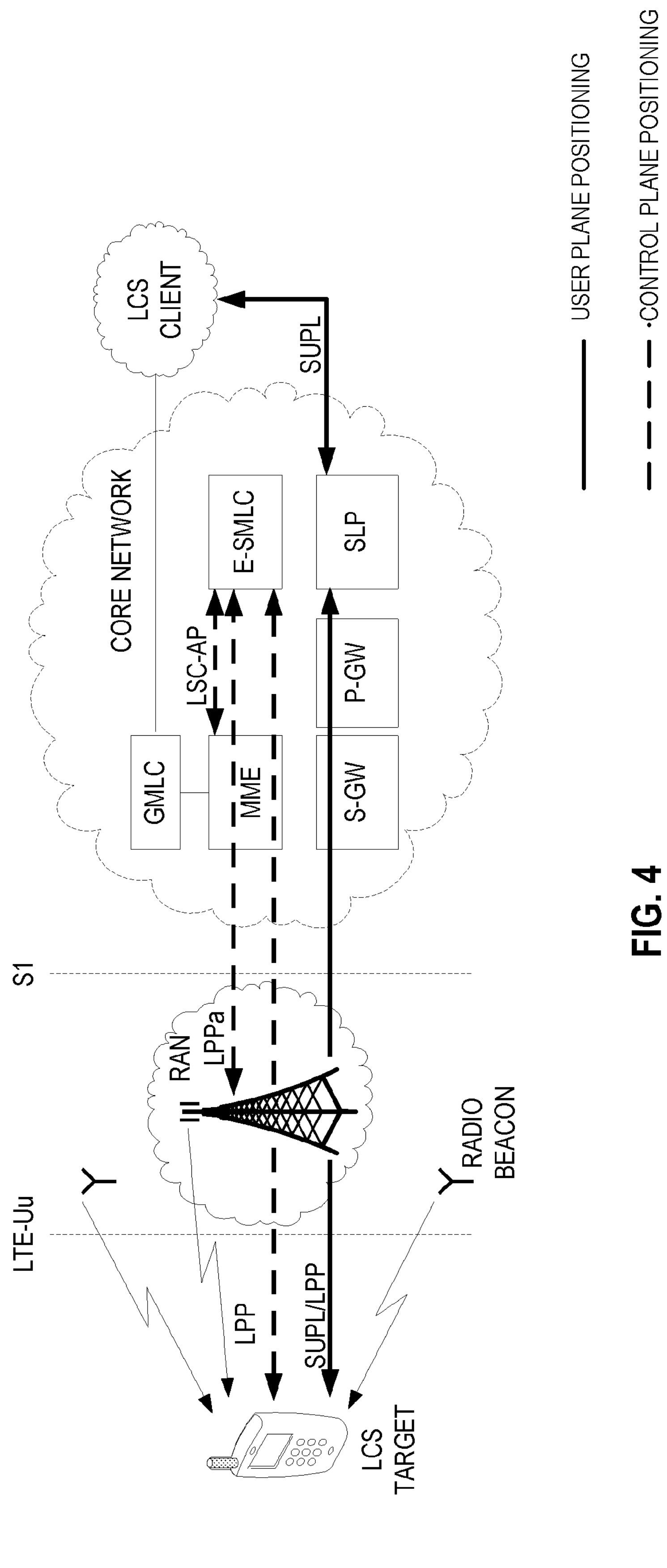
LCS CLIENT
SUPL
CORE NETWORK
E-SMLC
SLP
LSC-AP
P-GW
GMLC
MME
S-GW
S1
RAN
LPPa
LTE-Uu
RADIO BEACON
LPP
SUPL/LPP
LCS TARGET
USER PLANE POSITIONING
CONTROL PLANE POSITIONING

FIG. 4

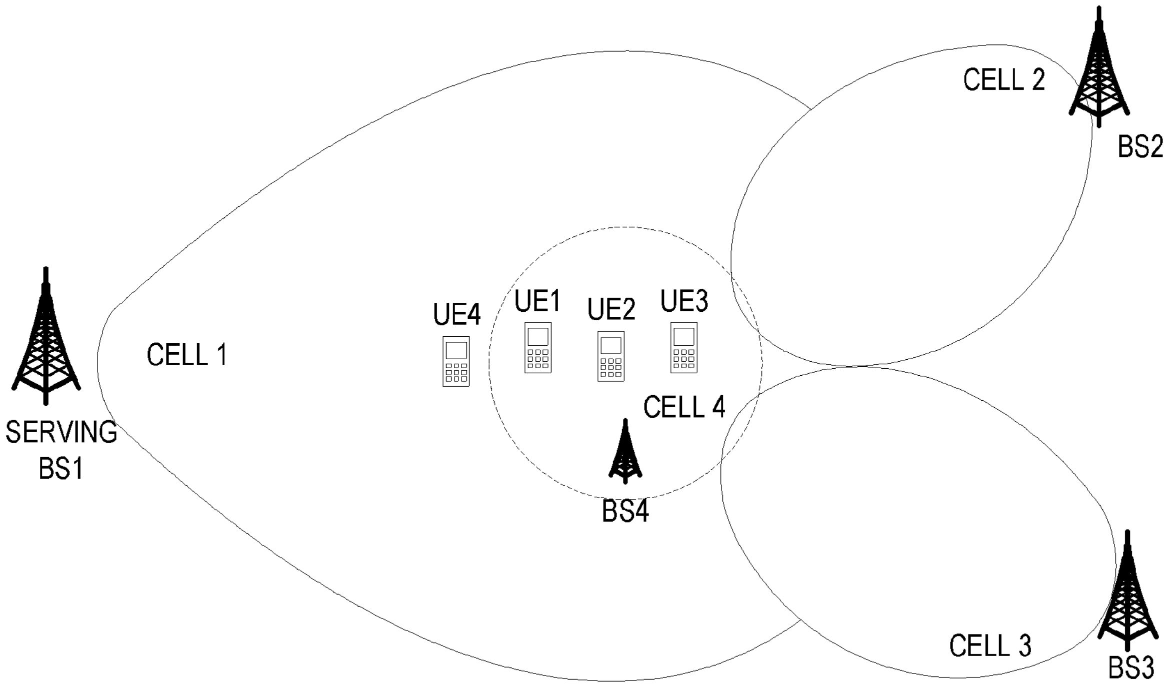
CELL 2
BS2
SERVING
BS1
CELL 1
UE4
UE1
UE2
UE3
CELL 4
BS4
CELL 3
BS3

FIG. 5

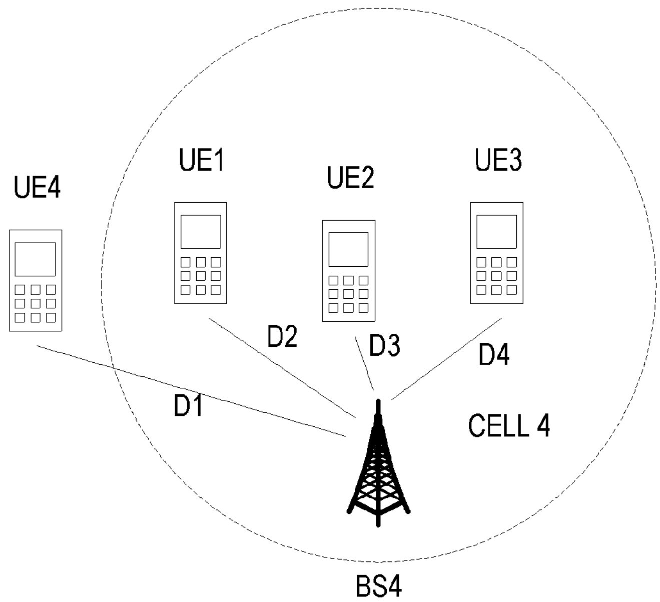

FIG. 6

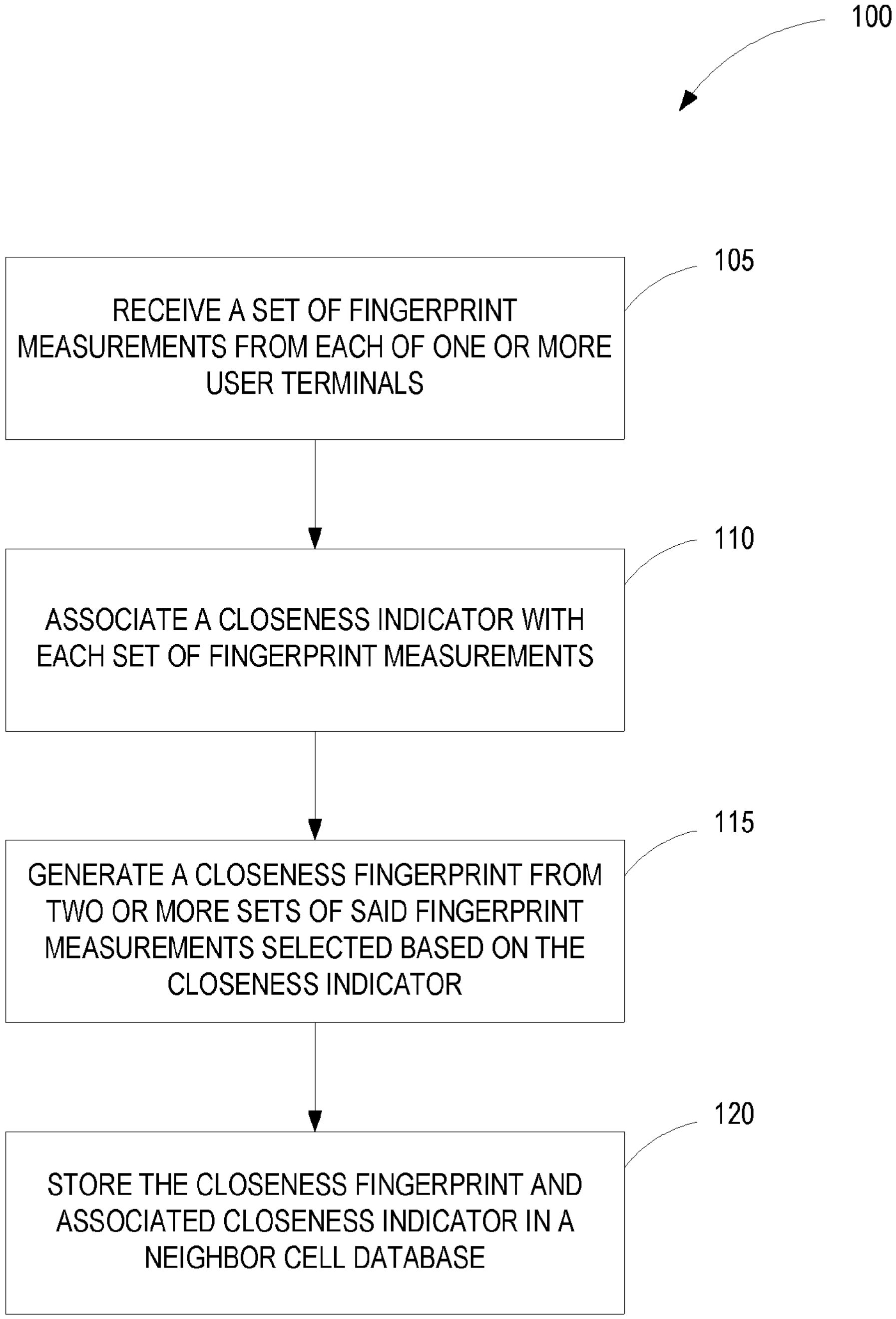
100
RECEIVE A SET OF FINGERPRINT MEASUREMENTS FROM EACH OF ONE OR MORE USER TERMINALS
105
ASSOCIATE A CLOSENESS INDICATOR WITH EACH SET OF FINGERPRINT MEASUREMENTS
110
GENERATE A CLOSENESS FINGERPRINT FROM TWO OR MORE SETS OF SAID FINGERPRINT MEASUREMENTS SELECTED BASED ON THE CLOSENESS INDICATOR
115
STORE THE CLOSENESS FINGERPRINT AND ASSOCIATED CLOSENESS INDICATOR IN A NEIGHBOR CELL DATABASE
120

FIG. 7

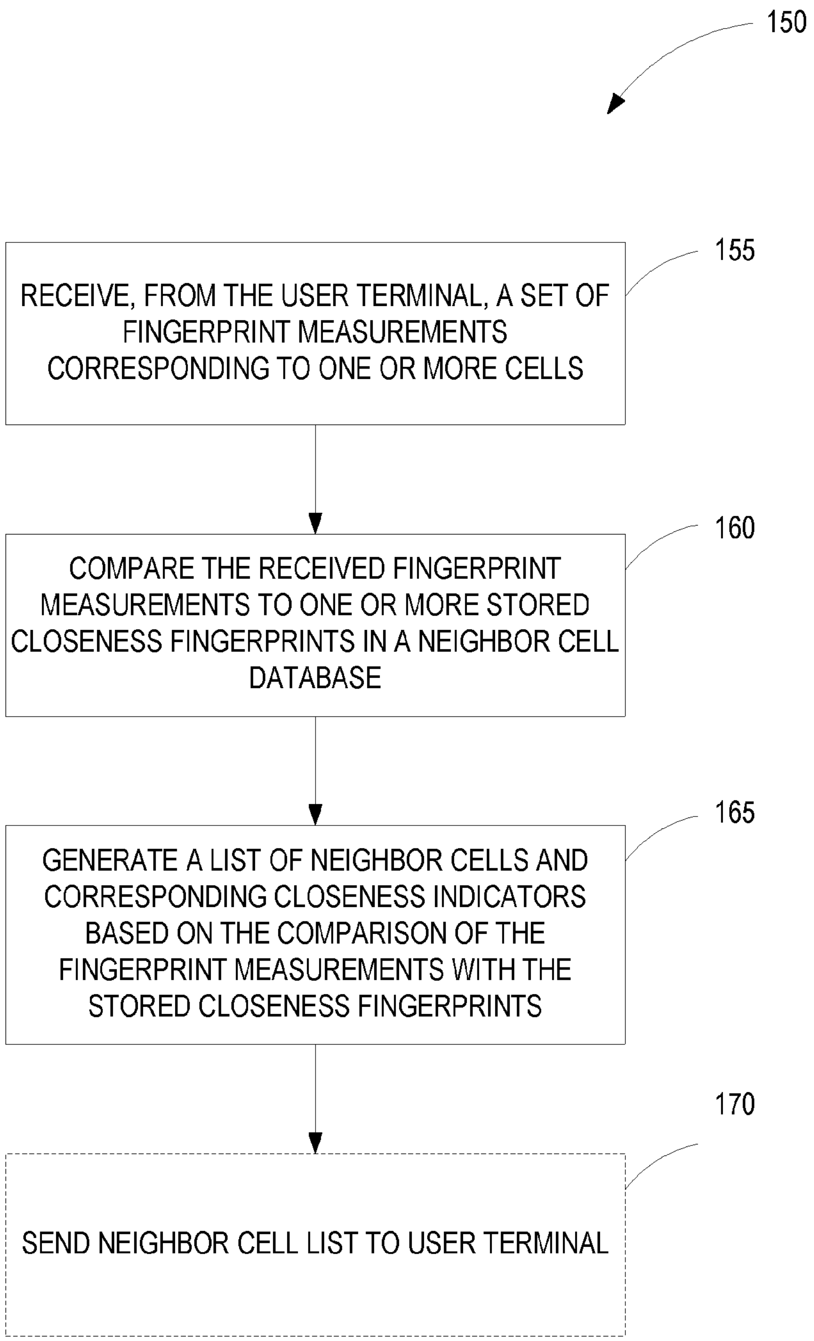
150
155
RECEIVE, FROM THE USER TERMINAL, A SET OF FINGERPRINT MEASUREMENTS CORRESPONDING TO ONE OR MORE CELLS
160
COMPARE THE RECEIVED FINGERPRINT MEASUREMENTS TO ONE OR MORE STORED CLOSENESS FINGERPRINTS IN A NEIGHBOR CELL DATABASE
165
GENERATE A LIST OF NEIGHBOR CELLS AND CORRESPONDING CLOSENESS INDICATORS BASED ON THE COMPARISON OF THE FINGERPRINT MEASUREMENTS WITH THE STORED CLOSENESS FINGERPRINTS
170
SEND NEIGHBOR CELL LIST TO USER TERMINAL

FIG. 8

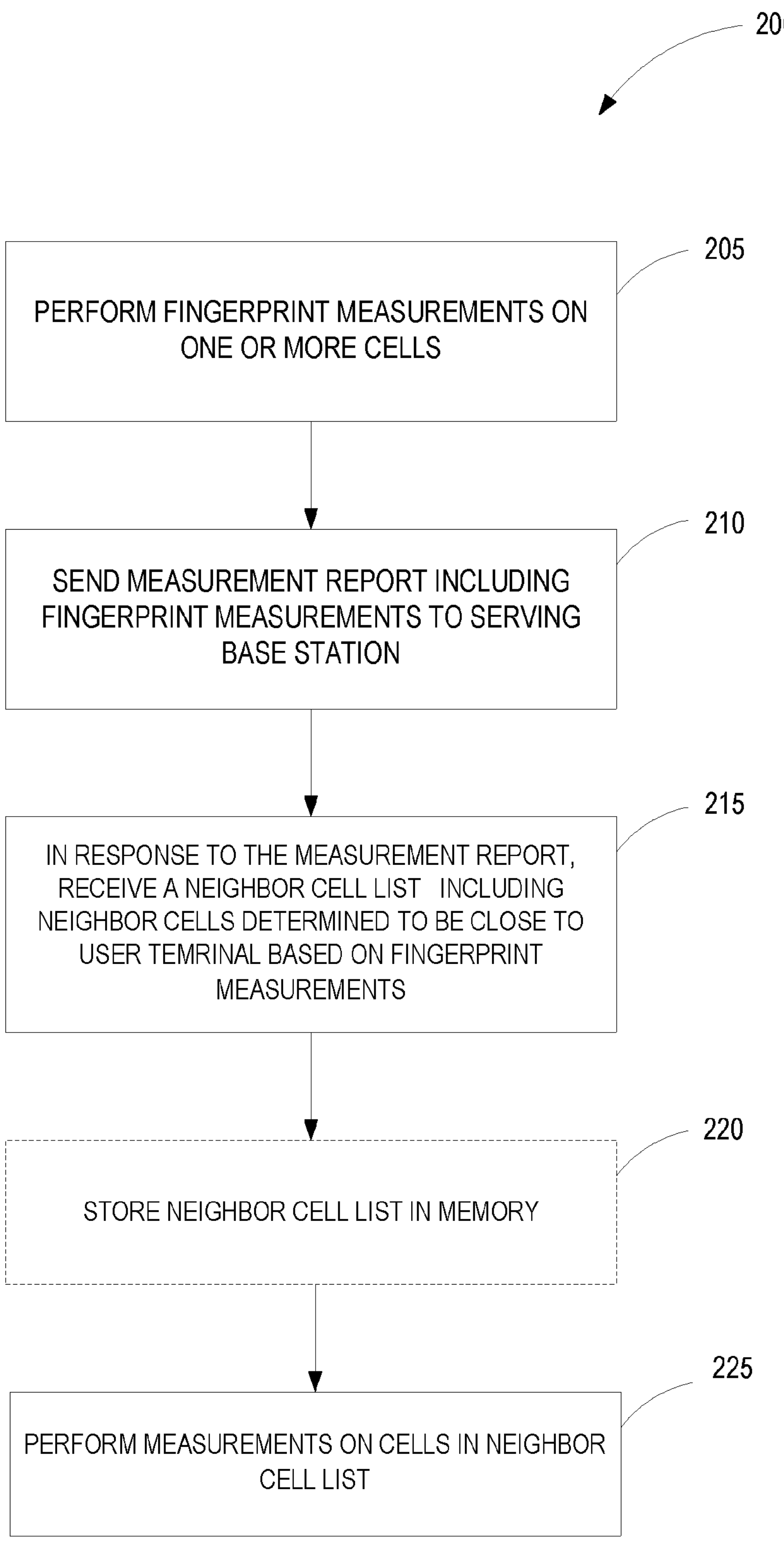
200
205
PERFORM FINGERPRINT MEASUREMENTS ON ONE OR MORE CELLS
210
SEND MEASUREMENT REPORT INCLUDING FINGERPRINT MEASUREMENTS TO SERVING BASE STATION
215
IN RESPONSE TO THE MEASUREMENT REPORT, RECEIVE A NEIGHBOR CELL LIST INCLUDING NEIGHBOR CELLS DETERMINED TO BE CLOSE TO USER TEMRINAL BASED ON FINGERPRINT MEASUREMENTS
220
STORE NEIGHBOR CELL LIST IN MEMORY
225
PERFORM MEASUREMENTS ON CELLS IN NEIGHBOR CELL LIST

FIG. 9

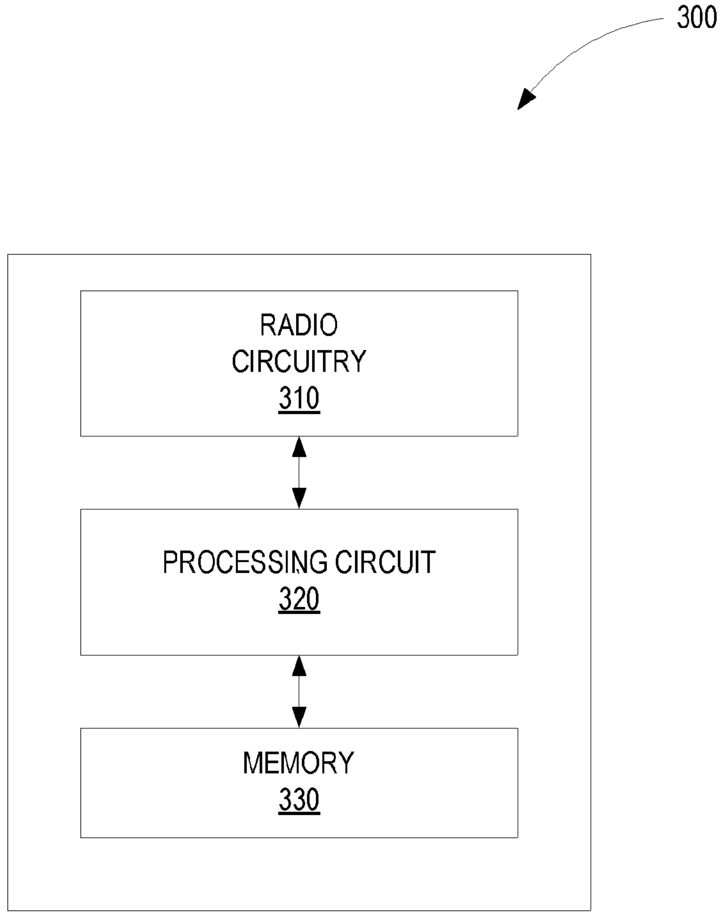

FIG. 10

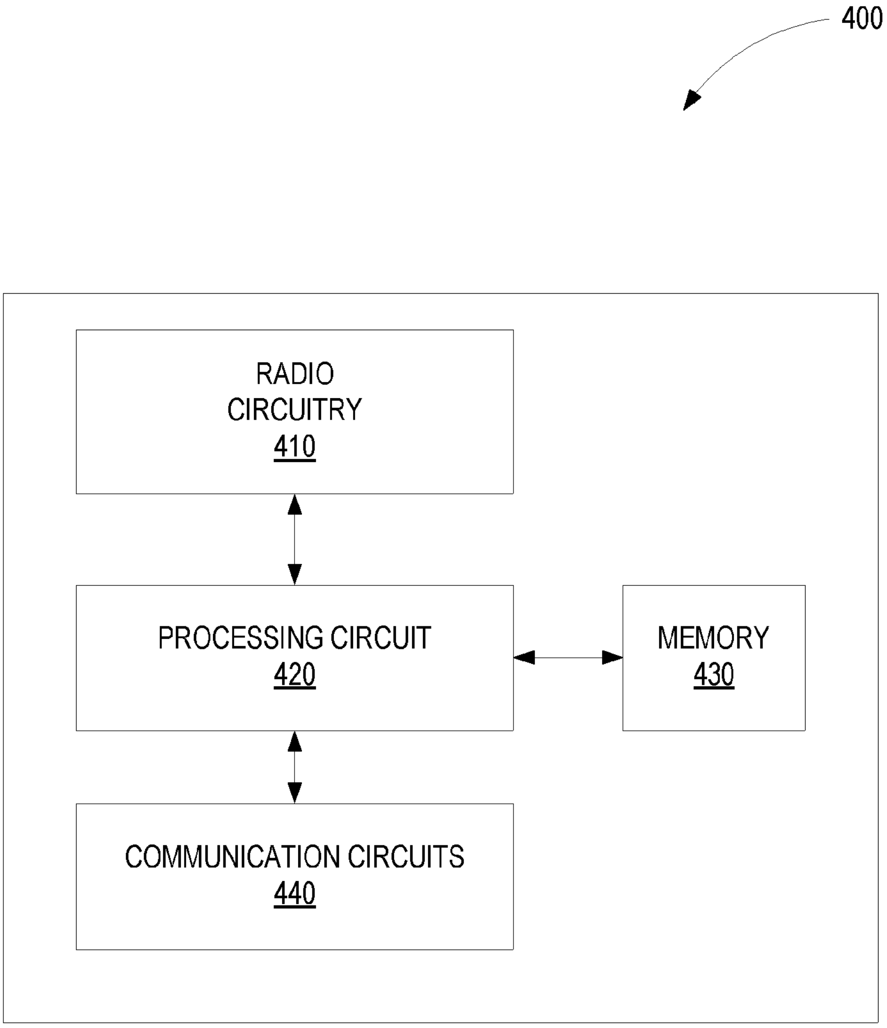
400
RADIO
CIRCUITRY
410
PROCESSING CIRCUIT
420
MEMORY
430
COMMUNICATION CIRCUITS
440

FIG. 11