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(54) Title: LOCATION MANAGEMENT OF A MOBILE TERMINAL IN A MOBILE COMMUNICATIONS NETWORK

(57) Abstract: A method, in a network node, for managing a location of a mobile terminal within a mobile communications network is disclosed, the network comprising a plurality of mobility areas, each divided into at least one sub-mobility area. The method comprises maintaining a location database for the mobile terminal (step 20), wherein the location database indicates a mobility area and a sub-mobility area of the mobile terminal. A computer program product for carrying out a method for managing a location of a mobile terminal in a mobile communications network is also disclosed. Also disclosed is a mobility management node (200, 300) in a mobile communications network, the network comprising a plurality of mobility areas, each divided into at least one sub-mobility area. The node comprises a mobile terminal location database (220, 206, 306), the location database comprising a mobility area field (224, 206b, 306b) and a sub-mobility area field (222, 206a, 306a).



**LOCATION MANAGEMENT OF A MOBILE TERMINAL IN A MOBILE
COMMUNICATIONS NETWORK**

Technical Field

5 The present invention relates to a method for managing a location of a mobile terminal within a mobile communications network. The invention also relates to a computer program product configured to carry out a method for managing a location of a mobile terminal and to a mobility management node in a mobile communications network.

10 Background

 The following discussion illustrates background to the present invention within the context of the GSM mobile communications standard. The issues discussed are equally applicable to other standards including UMTS and LTE. Where appropriate the
15 equivalent network entities according to alternative standards are indicated within the body of the text.

 A mobile communications network typically comprises a plurality of basestations, each of which provides wireless network coverage over an area known as a cell. The term
20 cell may refer to a basestation itself or to its coverage area, depending upon the context in which the term is used. Mobile user devices, referred to as mobile stations (MS), access network services via the basestations. A group of basestations may be managed via basestation controller (BSC). Alternatively, some or all of the functionality of a basestation controller may be incorporated within individual basestations. A part of
25 an example mobile communications network is illustrated at Figure 1, with a plurality of individual basestations 2 each having a coverage area or cell 4 and being controlled by a single basestation controller 6. Mobile stations 8 access network services via the basestations 2.

30 In order to improve system capacity, a basestation coverage area may be partitioned into multiple smaller areas, often referred to as sectors. In such cases, the supporting entity is often referred to as a base transceiver subsystem (BTS).

 Mobile stations (MS) within mobile communications networks such as that described
35 above are typically designed to operate in one of several modes. In an ACTIVE mode, the MS may actively exchange data with one or more basestations belonging to the

network. In an IDLE mode, which may also be referred to as a STAND BY mode, the MS does not actively exchange data but typically monitors a channel (PAGING channel PCH) for an alert indicating an incoming call.

5 By their nature, mobile stations may change location, and may move from the coverage area of one basestation into the coverage area of a different basestation. When a MS is in an ACTIVE mode, a hand over procedure, known as a "hand-off", is conducted, during which the new basestation is contacted and arrangements are made for the new basestation to serve the MS. This allows for a user of a MS in ACTIVE mode, for
10 example making or receiving a call, to experience a substantially seamless transition between service basestations. The hand-off procedure is, however a relatively high consumption process, and makes use of network resources that could otherwise be used for carrying traffic. For this reason, the hand-off procedure is only used when a MS in ACTIVE mode changes location.

15

A MS in IDLE mode may also change location, meaning that when the MS transitions back to ACTIVE mode, it will need to communicate through a different basestation to that with which it was communicating before it entered IDLE mode. As discussed above, the resource intensive hand-off process is not performed for MS in IDLE mode.
20 Therefore in the event of an incoming call, the network must first locate the MS in order to establish communication between the MS and its nearest basestation.

The network may locate a MS in IDLE mode by paging the MS in multiple cells and waiting for a paging response from the cell in which the MS is located. In order to
25 reduce the number of cells in which a MS must be paged, a location updating procedure is carried out. A Location Area (LA) is defined as comprising a group of cells and is assigned a unique identity, and the network tracks the location of a MS in IDLE mode via its location area. The term "Location Area" is used for circuit switched second and third generation mobile technologies. The equivalent concept in packet
30 switched second and third generation technologies is known as a Routing Area (RA), and in fourth generation technologies this is referred to as a Tracking Area (TA) or Tracking Area List (TAL). Whenever a MS moves to a cell belonging to a new location area, the location update procedure is triggered, and the MS informs the network of its location by sending a message known as a Location Updating Request. This message
35 may also be sent periodically to confirm the location of a MS that has not changed location area. The location updating request message is forwarded to the Visitor

Location Register (VLR) that has the appropriate current information about the location of the MS, and may also be forwarded to the Home Location Register (HLR) of the MS. Each VLR serves a mobile switching centre (MSC) which controls a service area comprising at least one, and frequently several, location areas.

5

The process of paging a mobile station is handled within the network in a hierarchical manner, progressing down the levels of the network hierarchy. When it is necessary to page a mobile station, the HLR of the mobile station is referred to. The HLR is a central database containing details of each subscriber authorised to use the GSM core network. The HLR includes a pointer to the MSC/VLR that controls the area within
10 which the MS is currently located. The MSC/VLR contains current information about the LA of the mobile station, and thus distributes a paging message for the mobile station to all BSCs that control cells within the LA of the MS. The BSCs then send the paging request to all basestations which they control and which are situated within the
15 relevant location area. The contacted basestations then send the paging signal over the air interface and await a reply from the mobile station.

The location updating procedure and use of location areas allow for more efficient paging of a mobile station in IDLE mode. However, a location area may still cover a
20 relatively large number of cells, as discussed in further detail below. The maximum number of cells that may be contained within a location area is 2^{16} , and although in practice the number of cells in a location area is likely to be less than the maximum, this still represents a significant number of cells. Paging a mobile station within such a large number of cells still represents a considerable drain on network resources. In
25 the event that a mobile station cannot be located within its location area, a global page may be conducted in all location areas under the control of a single MSC, which may include a vast number of cells and represent a still greater burden on network resources. One option to reduce this heavy resource usage for paging procedures is to reduce the size of location areas, meaning that paging within a location area involves
30 sending a paging signal in fewer cells. However, while the location updating procedure is less resource intensive than the hand-off procedure followed for cells in ACTIVE mode, the location update procedure still represents considerable network resource usage. During a location update procedure, security measures including Authentication, Authorization, Accounting (AAA), and Ciphering methods must be
35 carried out. It may also be necessary to contact and update the HLR of the MS during the location update procedure. Reducing the size of location areas would necessarily

increase the frequency of these location update procedures, as mobile stations would change location areas with greater frequency. Thus reducing the size of location areas would place an increased burden on all network levels, cancelling out any advantage gained in reduction of paging load.

5

Summary

It is an aim of the present invention to provide a method, node and computer program product which obviate or reduce at least one or more of the disadvantages mentioned
10 above.

According to a first aspect of the present invention, there is provided a method, in a network node, for managing a location of a mobile terminal within a mobile communications network, wherein the network comprises a plurality of mobility areas,
15 each divided into at least one sub-mobility area. The method comprises maintaining a location database for the mobile terminal, wherein the location database indicates a mobility area and a sub-mobility area of the mobile terminal.

The mobility and sub-mobility areas of the network may be defined according to
20 network requirements. In some examples, the mobility areas may correspond to Location Areas, Routing Areas, Tracking Areas, or Tracking Area Lists (TAL) according to the mobile communications standard according to which the network operates. In other examples, the mobility areas may be newly defined areas, greater or smaller than the existing area definitions discussed above. By maintaining at least two levels of
25 location data for a mobile station in a single network node, aspects of the present invention allow a finer degree of detail to be maintained at the node concerning the location of the mobile station, thus enabling more focussed paging of the mobile station and so reducing the resource burden of the paging process.

30 A mobile terminal may for example comprise a mobile station in a GSM network, or may comprise a User Equipment (UE) in a network operating under UMTS or LTE.

According to some embodiments, maintaining a location database for the mobile terminal may comprise updating a sub-mobility area of the mobile terminal in the
35 location database when the mobile terminal enters a new sub-mobility area; and updating a sub-mobility area and a mobility area of the mobile terminal in the location

database when the mobile terminal enters a new mobility area. In this manner, both levels of location data are updated according to the nature of the change in location of the mobile terminal. If the mobile terminal changes only a sub-mobility area, the new sub-mobility area is updated in the location database. However, if the mobile terminal
5 changes a mobility area, both the new sub-mobility area and the new mobility area are updated in the location database. The network node may thus maintain a dual level of detail concerning the location of the mobile terminal.

According to some embodiments, maintaining a location database may comprise
10 receiving a sub-mobility area update request from the mobile terminal and updating the location database with the new sub-mobility area contained in the sub-mobility area update request. The sub-mobility area update request may in some examples comprise a Direct Transfer Application Part (DTAP) message. A new DTAP message for sub-mobility area update may be defined, for example within the Protocol
15 Discriminator (PD) field for Mobility Management (MM) messages. According to such examples, the mobile terminal may determine that it has entered a new sub-mobility area and may send a sub-mobility area update request.

According to some embodiments, maintaining a location database may comprise
20 receiving a mobility area update request from the mobile terminal, extracting a new sub-mobility area of the mobile terminal from the mobility area update request, updating the location database with the new sub-mobility area of the mobile terminal, and updating the location database with the new mobility area contained in the mobility area update request. According to such examples, the mobile terminal may determine
25 that it has entered a new mobility area and may send a mobility area update request.

According to further embodiments, maintaining a location database may further comprise, following receipt of a sub-mobility area update request and updating of the sub-mobility area in the location database, mapping the new sub-mobility area to a
30 corresponding new mobility area, comparing the new mobility area to a stored mobility area for the mobile terminal in the location database, and updating the mobility area of the mobile terminal in the location database if the new mobility area is different to the stored mobility area. According to such embodiments, the mobile terminal may identify only changes in sub-mobility area, and may send a sub-mobility area update request
35 for every change in sub-mobility area, even when that change also corresponds to a change in mobility area. The network node may perform a mapping and comparison

operation to determine on receipt of each sub-mobility update request, whether the change in sub-mobility area also involves a change in mobility area, and may update the mobility area of the mobile station in the location database accordingly.

5 According to some embodiments, the method may further comprise, if the new mobility area is different to the stored mobility area, modifying the sub-mobility area update request to replace the new sub-mobility area with the corresponding new mobility area; and forwarding the modified sub-mobility area update request to another network node. In this manner, according to certain embodiments of the invention, the method may
10 allow a network node to operate as a gateway between deferent network nodes and different hierarchy levels operating at different levels of location detail. Thus a mobile terminal may operate within a fine level of detail, concerned only with sub-mobility areas, while other network nodes may be concerned only with the larger mobility areas. Embodiments of the present invention allow a network node to facilitate communication
15 between the mobile terminal and different nodes by modifying the sub-mobility area update request to replace the new sub-mobility area with the corresponding new mobility area before forwarding the modified sub-mobility area update request to another network node. The other network node may be on a higher hierarchical level than the network node.

20 According to some embodiments, the method may further comprise receiving a message from the mobile terminal containing a current sub-mobility area of the mobile terminal, modifying the message to replace the sub-mobility area with a corresponding mobility area of the mobile terminal, and forwarding the modified message to another
25 network node. The other network node may be on a higher hierarchical level than the network node.

According to some embodiments, the method may further comprise receiving a message from another network node for the mobile terminal, the message containing
30 the mobility area of the mobile terminal, retrieving from the location database the sub-mobility area of the mobile terminal, modifying the message to replace the mobility area with the sub-mobility area of the mobile terminal, and forwarding the message to the mobile terminal. The other network node may be on a higher hierarchical level than the network node.

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Embodiments of the invention thus allow the network node to act as a gateway as described above for other communication messages passed from and to the mobile terminal, in addition to sub-mobility update requests.

5 According to some embodiments, modifying a message may comprise one of a bit replacement process or a hashing process. According to some examples of the invention, sub-mobility areas may be identified using a bit stealing process, employing bits from a mobility area identity to represent the sub-mobility area or areas into which the mobility area is divided. In such examples, modifying may comprise hiding or
10 adding the additional bits designating the sub-mobility area. In other examples, the correspondence between sub-mobility areas and mobility areas may be captured by a hashing function, which may be performed to replace a sub-mobility area with a mobility area in a message being passed to a network node.

15 According to some embodiments, the method may further comprise paging the mobile terminal within the sub-mobility area stored for the mobile terminal in the location database. By paging the mobile terminal within the sub-mobility area that represents a finer grain of detail than the mobility area, the network resource requirement for the paging procedure may be reduced.

20

According to some embodiments, if no reply is received to the paging in the sub-mobility area, the method may further comprise consulting a paging parameter for the mobile terminal and conducting a repeat page according to the status of the paging parameter. The paging parameter may be configurable according to network
25 requirements or priorities. For example, the paging parameter may direct differing repeat page actions for a network prioritising locating a mobile terminal over resource wastage compared to a network prioritising resource efficiency.

According to some embodiments, the repeat page may comprise at least one of: (i) a
30 zero page in which the mobile terminal is flagged unreachable, (ii) a sub-mobility area page, (iii) a mobility area page, (iv) a page across multiple mobility areas. Pages may be conducted using one or both of a temporary or unique identifier for the mobile terminal. Each of these repeat page actions may represent a different balance between the likelihood of successfully locating the mobile terminal and the associated
35 resource cost. Repeat paging actions may be sequentially escalated and/or repeated according to the configurable paging parameter and its reflection of network priorities.

According to another aspect of the present invention, there is provided a computer program product configured, when run on a computer, to carry out a method according to the first aspect of the present invention. The computer program product may be
5 stored on a computer-readable medium, or it could, for example, be in the form of a signal such as a downloadable data signal provided from an Internet website, or it could be in any other form.

According to another aspect of the present invention, there is provided a mobility
10 management node in a mobile communications network, wherein the network comprises a plurality of mobility areas, each divided into at least one sub-mobility area. The node comprises a mobile terminal location database, wherein the location database comprises a mobility area field and a sub-mobility area field. The mobility management node is thus configured to maintain at least two levels of detail
15 concerning the location of a mobile terminal in the network. The mobility management node may for example comprise one of a MSC, BSC, Serving GPRS Serving Node (SGSN), Radio Network Controller (RNC) or Mobility Management Entity (MME), according to different embodiments of the invention and the particular standard according to which the network of which the node is a part operates.

20 According to some embodiments, the node may further comprise an updating unit, configured to update the sub-mobility area field and the mobility area field of the location database. The node may further comprise a receiving unit and a sending unit configured to receive and send messages to/from a mobile station and/or other network
25 nodes

According to some embodiments, the updating unit may comprise a sub-mobility area updating sub-unit and a mobility area updating sub-unit.

30 According to some embodiments, the node may further comprise a mapping unit configured to map between sub-mobility areas and corresponding mobility areas, and a comparison unit; configured to compare data from the mapping unit and the location database.

35 According to some examples, the node may further comprise a modifying unit configured to modify location data of messages processed by the node.

According to further embodiments, the node may further comprise a paging unit configured to page a mobile terminal in a sub-mobility area. The paging unit may also be configured to page in other areas according to a status of a paging parameter.

5

Brief description of the drawings

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the following drawings in which:

10

Figure 1 illustrates a part of an example mobile communications network;

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Figure 2 is a flow chart showing process steps in a method, in a network node, for managing a location of a mobile terminal;

Figure 3 illustrates functional units in a mobility management node;

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Figure 4 illustrates a Signalling Protocol Layer between a base station system and a mobile switching centre;

Figure 5 is a flow chart illustrating process steps conducted in a method according to that of Figure 2;

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Figure 6 is a signalling flow diagram for the process of Figure 5;

Figure 7 is a flow chart illustrating process steps in another method according to that of Figure 2;

30

Figure 8 is a signalling flow diagram for an example process according to Figure 7;

Figure 9 illustrates functional units in another mobility management node;

35

Figure 10 is a flow chart illustrating process steps in another method according to that of Figure 2;

Figures 11 and 12 are flow charts illustrating process steps in further methods according to that of Figure 2;

Figure 13 is a flow chart illustrating process steps for relaying messages between a
5 mobile terminal and a network node;

Figure 14 is a flow chart illustrating process steps for managing a database;

Figure 15 illustrates functional units of another mobility management node;
10

Figure 16 is a flow diagram illustrating a paging strategy.

Detailed Description

15 As discussed above, and illustrated in Figure 2, aspects of the present invention provide a method, in a network node, for managing a location of a mobile terminal within a mobile communications network, wherein the network comprises a plurality of mobility areas, each divided into at least one sub-mobility area. Some or all of the mobility areas may be divided into a plurality of sub mobility areas, where a plurality
20 refers to two or more sub-mobility areas. The method comprises, in a step 20, maintaining a location database for the mobile terminal, wherein the location database indicates a mobility area and a sub-mobility area of the mobile terminal. The network node may be a mobility management node 200 of the network. The node 200 may comprise a location database 220 having a sub-mobility area field 222 and a mobility
25 area field 224, as illustrated in Figure 3.

The step 20 of maintaining the location database for the mobile terminal may comprise a first step 22 of updating a sub-mobility area of the mobile terminal in the location database when the mobile terminal enters a new sub-mobility area, and a second step
30 24 of updating a sub-mobility area and a mobility area of the mobile terminal in the location database when the mobile terminal enters a new mobility area. The process by which the updating steps 22 and 24 are accomplished may vary, depending upon the manner in which the mobility area and sub-mobility areas are handled within the network. According to some embodiments of the invention, mobile terminals and
35 multiple hierarchical levels of network nodes may distinguish between mobility areas and sub-mobility areas. According to such embodiments, mobile terminals and multiple

network levels may maintain the same global location view in which mobility areas are divided into sub-mobility areas, and the updating steps may be conducted on the basis of messages distinguishing between sub-mobility and mobility areas. According to other embodiments, different views may be held at different network levels, with
5 different levels dealing in different degrees of location detail. For example, mobile terminals and optionally certain lower network node levels may operate exclusively within sub-mobility areas, with no awareness of the larger mobility areas. Higher level network nodes may operate exclusively within mobility areas, with no awareness of the finer grained sub-mobility areas. According to such embodiments, the mobility
10 management node may act as a gateway, maintaining both views and enabling communication between the different views. According to these embodiments, the updating steps may comprise additional sub steps to manage messages received and send to/from entities having different viewpoints. Examples of these different embodiments are discussed in detail below.

15

As mentioned above, mobility areas according to the present invention may correspond to different location entities according to different embodiments and different network operating standards. In one embodiment, mobility areas may correspond to Location Areas, Routing Areas, Tracking Areas, or Tracking Area Lists (TAL) according to the
20 mobile communications standard in accordance with which the network operates. Sub-mobility areas may thus be smaller subdivisions of location areas, routing areas etc. In other embodiments, mobility areas may comprise groupings of location areas, routing areas etc, such that for example a mobility area may comprise a group of location areas, in effect a "super-location area", while sub-mobility areas comprise subdivisions
25 of the original location areas, thus equating to "sub-location areas". In still further embodiments, a network configuration may be completely restructured, such that mobility areas do not have a direct correspondence relation with existing location areas, routing areas etc. It is envisaged that sub-mobility areas may represent a finer level of location detail than existing location areas, routing areas, tracking areas and
30 tracking area lists, however this is may not necessarily be the case.

For the purposes of illustration, the following discussion of embodiments of the invention explains the embodiments with reference to a GSM network in which mobility areas correspond to location areas, with sub-mobility areas representing subdivisions
35 of these location areas, and referred to as sub-location areas, or sub-LAs. The principles of the invention are equally applicable to other standards and other

correspondence relations between mobility areas, sub mobility areas and existing structures. A brief discussion of equivalent procedures/entities may be found at the end of the present description section.

- 5 In order to provide context for the following discussion of embodiments, a brief explanation of location area identities in a GSM network is provided below.

According to the 3GPP technical specification group core network 3GPP TS 23 V4.9.0; V5.2.0, V8.1.1, and V9.0.0 for Global system for mobile communications, a location
10 area identity (LAI) and cell global identity (CGI) are defined as follows:

Location Area Identity (LAI) comprises: MCC+MNC+LAC

MCC, Mobile Country Code, identifies the country code in which the Public Land
15 Mobile Network (PLMN) is located. The value of MCC is the same as the 3-Digit MCC contained in International Mobile Subscriber Identity (IMSI) for mobile stations.

MNC, Mobile Network Code, identifies the PLMN in the country of the MCC. The MNC
takes the same value as the 2 or 3 digit MNC contained in IMSI.

20

LAC, Location Area Code LAC, is a 2 octet number identifying a location area within the PLMN. It can be coded using a full hexadecimal representation except for the hexadecimal values 0000 and FFFF, which are reserved for use in special cases where no valid LAI exists.

25

Cell Global Identity (CGI) comprises: MCC+MNC+LAC+CI

CI, Cell Identifier is a 2 octet number identifying a cell within a location area. It can be coded using a full hexadecimal representation.

30

From the above explanation it can be seen that a PLMN can have up to 2^{16} location areas, and each location area can have 2^{16} cells, meaning that a PLMN can have a maximum of 2^{32} cells. In practice, the actual number of cells in a PLMN is typically much smaller than the maximum number.

35

According to a first embodiment of the present invention, as discussed above, the mobile stations and multiple hierarchical levels of network nodes may distinguish between location areas and sub-location areas. According to this embodiment, mobile stations and multiple network levels maintain the same global location view in which location areas are divided into sub-location areas, and thus the updating steps discussed above are conducted on the basis of messages distinguishing between sub-location and location areas.

In order to distinguish between different sub-LAs, several bits of the location area identity of a location area may be used to represent sub-LAs of that location area. This process of using bits from an LAI to represent corresponding sub-LAs is referred to as bit stealing. According to this process, the 2 octets (16 bits) of the LAC are divided into two parts, one representing the location area and the other the sub-location area.

Let N be the number of bits representing a sub-LA within a particular LA. According to the bit stealing process, up to 2^N sub-LAs can be defined within up to 2^{16-N} LAs. For instance with $N = 2$, up to 2^2 sub-LAs can be defined within up to 2^{14} LAs. The number of cells per LA is unaffected by the bit stealing meaning that there may still be up to 2^{16} cells per LA. With $N = 2$, the number of cells within a single sub-LA may be up to one quarter the total number of cells in the LA. This represents a considerable reduction in cell numbers which may result in a significant reduction in paging load if a mobile station is paged within a sub-LA as opposed to within a LA. The value of N , and hence the number of sub-LAs per LA, and also the number of LAs, can be selected according to network requirements. A balance may be struck between reduced paging load from smaller sub-LAs and increased sub-LA update procedures.

In order to take advantage of the newly defined sub-LAs during the paging procedure, it is necessary for the network node controlling the paging procedure to have knowledge of the sub-LA location of a mobile station. According to aspects of the present invention, this node, the mobility management node, maintains a location database indicating a location area and a sub-location area of a mobile station. This node may according to the present example be the MSC/VLR. According to the present embodiment, changes in location area may be notified substantially according to a known location updating procedure, with small amendments as discussed below. In order to inform the MSC/VLR about changes in sub-location area, two new Direct Transfer Application Part (DTAP) messages may be introduced: Sub-Location Area

Update Request and Sub-Location Area Update Response. These two new messages are introduced within the Protocol Discriminator (PD) field for Mobility management (MM) messages. These messages are exchanged between mobile station and the MSC for conveying the sub location area identity to VLR.

5

The Direct Transfer Application Part (DTAP) is used to transfer call control and mobility management messages between the MSC and the mobile station. The DTAP information in these messages is not interpreted by the basestation subsystem (BSS). Messages received from the mobile station are identified as DTAP by the Protocol Discriminator Information Element. The majority of radio interface messages are transferred across the BSS-MSC interface by DTAP, except for messages belonging to the Radio Resource (RR) management protocol.

The DTAP function is in charge of transferring layer 3 messages between the mobile station and the MSC without any analysis of the message contents. The interworking between the layer 2 protocol on the radio side and signalling system 7 at the landside is based on the use of individual Signalling Connection Control Part (SCCP) connections for each mobile station and on a distribution function. An illustration of the Signalling Protocol Layer between the BSS and the MSC is given in Figure 4, together with the DTAP signalling format used according to the present embodiment for sending sub-LA update requests. Within the DTAP signalling format, the Protocol Discriminator (PD) distinguishes between messages belonging to different procedures including Call Control, Radio Resource Management, Supplementary Service Control and Mobility Management.

25

Figures 5 and 7 are flow charts illustrating process flow within a mobile management node in the form of a MSC/VLR on receipt of a sub-location area update request and a location area update request from a mobile station.

With reference to Figure 5, on receipt of a sub-location area update request from a mobile station at step 32, the MSC/VLR updates the sub-LA of the mobile station in its location database at step 34 and then sends a sub-LA update confirm message to the mobile station at step 36, terminating the update procedure. The identity of the new sub-LA, as expressed in the N bits reserved for this purpose in the LAI, is included in the sub-LA update request sent by the mobile station. This may simply be read by the MSC/VLR and placed into the location database entry for the mobile station.

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Figure 6 illustrates the signalling flow according to the above process of Figure 5. On discovering that it has moved into a new sub-location area within the same location area, the mobile station sends a Sub-LA update request at step 30. This message is sent on DTAP signalling as described above. After receiving the message at step 32 and updating the sub-LA of the mobile station in the location database at step 34, the serving MSC/VLR sends a sub-LA update response at step 36. No other network nodes are involved as the MSC/VLR holds the location area and sub-location area of the mobile station in its location database, and no security measures (AAA or ciphering) are performed.

Figure 7 illustrates the process flow on receipt of a location area update request from a mobile station. In a first step 42 the MSC/VLR receives a location area update request from the mobile station. The location area update request may be a standard location area update request message, including the identity of the new location area (new LAI). On receipt of the message, the MSC/VLR extracts from the LAI the N bits representing the sub-LA, and thus extracts the new sub-LA of the mobile station at step 44. The MSC/VLR then updates its location database with the new sub-LA of the mobile station at step 46, and updates its location database with the new location area of the mobile station at step 48. The MSC/VLR then sends a location area update response message to the mobile station at step 50. The step 48 of updating the location area of the mobile station in the location database of the MSC/VLR may comprise a plurality of additional sub steps including security procedures. This step may also comprise communication with other nodes such as the HLR of the mobile station, for example if the former location area is served by a different MSC/VLR. In such cases, the step 46 of updating the sub-LA of the mobile station may also involve additional steps in order to obtain an identifier for the mobile station.

Figure 8 illustrates signalling flow according to an example process as illustrated in Figure 7. Figure 8 illustrates signalling flow in a situation in which a mobile station moves from a former location area under control of a first MSC/VLR to a new location area under control of a second MSC/VLR. On discovering that it has moved to a new location area, the mobile station sends, at step 40, a location area update request to the MSC/VLR that is now its serving network entity. The MSC/VLR extracts the new sub-LA identity from the LAI in the update request message and obtains the identifier of the mobile station from the MSC/VLR serving the former location area of the mobile

station via ID request message 41a and ID response message 41b. The new MSC/VLR may then create an entry in its location database for the newly arrived mobile station with the received identifier and the extracted sub-LA.

- 5 The MSC/VLR then proceeds to perform its usual location updating procedure via update request and response messages 43a, 43b sent to and received from the HLR of the mobile station, subscriber data and subscriber data response messages 45a, 45b received from and sent to the HLR, and cancel location and cancel location response messages 47a, 47b, sent between the HLR and the MSC/VLR serving the former
10 location area of the mobile station (cancelling the location in the previous network entity). Finally, the MSC/VLR sends a location update confirmation message to the mobile station at step 50.

The processes of the presently described embodiment may be performed under the
15 control of a computer program which may cause a network node to execute the described process steps. Figure 9 illustrates functional units of the MSC/VLR node according to the presently described embodiment. The functional units of the node may execute the above described steps for example according to computer readable instructions received from a computer program. The MSC/VLR illustrated functions as
20 a mobility management node 200 comprising a send/receive unit 202, an updating unit 204, a location database 206 and a paging unit 208. The updating unit 204 comprises first and second sub-units 204a, 204b, dedicated to updating the sub location area and location area fields 206a, 206b of the location database 206. It will be understood that the units of the apparatus are functional units, and may be realised in any appropriate
25 combination of hardware and/or software.

The send/receive unit 202 is configured to send and receive messages to/from mobile stations and other network nodes. The updating unit 204 is configured to identify and forward sub-LA update requests and LA update requests to the relevant sub-unit 204a,
30 204b. The sub-LA updating sub unit 204a is configured to update the sub-LA field 206a of the location database 206 according to the process described with reference to Figure 5. The LA updating sub unit 204b is configured to update the LA field 206b of the location database 206 and to forward an extracted sub-LA to the sub-LA updating unit as described above with reference to Figure 7. The paging unit 208 is configured
35 to manage a paging process as described below with reference to Figure 16.

It will be appreciated that additional functional units and/or database fields may be included in the node 200 to enable the functionality discussed above. For example, the location database 206 may comprise an identity field containing either or both of a TMSI or IMSI for mobile stations whose locations are stored in the database. In addition, the node may further comprise a searching unit, operable to search the database for a particular mobile station, for example when receiving a paging request for a mobile station in order to extract the location of the mobile station from the database.

10 The above discussion of processes according to a first embodiment illustrates how a network may manage a sub-location area and a location area of a mobile station when multiple levels of the network, including the mobile station, can distinguish between sub-location areas and location areas, and may communicate accordingly.

15 The following discussion illustrates how a network may manage a sub-location area and a location area of a mobile station when different network levels maintain different location views. The mobility management node at which the processes described below are carried out thus acts as a gateway, facilitating communication between levels having different viewpoints. According to a second embodiment of the present invention, the mobility management node is the MSC/VLR, and thus acts as gateway for an entire MSC service area or region. According to a third embodiment of the present invention, the mobility management node is a basestation controller (BSC) and thus acts as gateway between its controlling MSC/VLR and mobile stations communicating via basestations under its control.

25 According to the second and third embodiments of the present invention, the process of bit stealing, as described above, may be used to identify sub-location areas within their corresponding location areas. Alternatively, separate identifiers may be used for location areas and sub-location areas. In some examples, a hashing function may be used to convert sub-LA identifiers to the identifier of the LA in which they are situated, such that the hash of a sub-LA results in the corresponding LA. In other examples, a mapping table may be maintained, allowing a mobility management node to look up the corresponding location area for a given sub-location area.

35 According to the second embodiment of the present invention, mobile stations and basestation controllers maintain a first view of the network, in which the network is

divided into sub-location areas. Mobile stations and basestation controllers view these divisions as location areas, being unaware of the larger division location areas seen by higher levels. Thus on crossing a location boundary, the mobile station sends what it considers to be a location area update message with the identity of the new area it has entered. The identity is considered by the mobile station to be its new location area, although viewed from the mobility management node, the identity is in fact the identity of the sub location area entered by the mobile station. According to this embodiment, HLRs and other higher level network nodes maintain a second view of the network, in which the network is divided into location areas only. The higher level nodes are unaware of the division into smaller sub-location areas and deal only with location areas. The mobility management node is the only network node level at which both views of the network are maintained. The mobility management node views both sub-location areas and location areas, and stores the relation between them. Thus the mobility management node views update requests from mobile stations as sub-location area update requests, and performs a translation between sub-location areas and location areas in order to forward certain requests and messages from the mobile station to higher level network nodes. This translation may be conducted for example on the basis of bit stealing, a hashing function and/or a mapping table.

An advantage of the dual view arrangement of the second embodiment is that only the mobility management node is aware that location management procedures are other than the standard procedures. Mobile stations and basestation controllers continue to act as in existing processes, sending location updates at "location area" boundaries. It is only at the level of the mobility management node that a distinction is made between a change of sub-LA within the same LA and a change of sub-LA that also equates to a change in LA. This distinction may be made on the basis of a mapping table and comparison between new and old LA identities. On the basis of this distinction, the mobility management node may take appropriate action for a sub-LA update or a LA update.

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Figure 10 is a flow chart illustrating process steps carried out at a MSC/VLR according to the second embodiment. In a first step 60, the MSC/VLR receives a sub-location area update request from a mobile station. As discussed above, from the viewpoint of the mobile station, this request is a location area update, however, from the viewpoint of the MSC/VLR it is a sub-location area update. For the purposes of clarity, Figure 10

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and the following discussion are presented from the viewpoint of the MSC/VLR, which maintains both views of the network and thus distinguishes between sub-LAs and LAs.

On receiving the sub-location area update request, the MSC/VLR maps the new sub-
5 LA identity to its corresponding LA identity in step 62. If the above described process of bit stealing is used for identifying sub-location areas, this mapping procedure may comprise merely separating the sub-LA identifier into its component sub-LA and LA parts. However, if an alternative procedure, such as a hashing function is used, the mapping process may comprise applying the hashing function, or consulting a mapping
10 table to identify the location area of which the new sub-location area forms a part.

At step 64, the MSC/VLR compares the new location area identity to the location area identity stored for the mobile station in the location area database. If the new and stored location area identities are the same (Yes at step 64), this indicates that the
15 mobile station has changed sub-location areas within the same location area, and a sub-location area update procedure may then be followed. In this case, the MSCV/VLR proceeds at step 66 to update the sub-location area of the mobile station in its location database and to send a normal update confirmation message to the mobile station at step 68, so terminating the procedure. If, however, the new and stored
20 location area identities are not the same (No in step 64), this indicates that the mobile station has moved into a sub-location area that is part of a new location area, and a location area update procedure may then be followed. In this case, the MSC/VLR still updates the sub-location area of the mobile station in the location database at step 70. The MSC/VLR then modifies the sub-location area identifier at step 72, to cause the
25 identifier to reflect the new location area of the mobile station. Where bit stealing is used to identify sub-location areas, this modifying procedure may comprise masking the bits of the identity that correspond to the sub-location area, so that only the bits corresponding to the location area are seen. If hashing is used, this modifying process may comprise applying the hashing function or consulting a mapping table to replace
30 the new sub-location area identity with the identity of the location area of which the new sub-location area forms a part.

Having modified the sub-location area identifier to cause it to reflect the corresponding location area, the MSC/VLR then proceeds to store the new location area identifier in
35 its location database and to continue with steps of a standard location update procedure at step 74. As discussed above, this may involve communicating with the

HLR and with a former serving MSC/VLR depending upon the nature of the LA change and upon network procedures. Once the MSC determines that the location update procedure is complete except for the final confirmation to the mobile station, the MSC/VLR proceeds at step 76 to send a normal update confirmation message to the mobile station, terminating the procedure. This confirmation message contains the full sub-LA identity of the new sub-LA of the mobile station, and thus corresponds to the sub-LA area update request sent by the mobile station. It will thus be appreciated that the mobile terminal is unable to tell the difference between an update confirmation message sent at step 68 following a sub-location update procedure, and an update confirmation message sent at step 76 following a location area update procedure.

The above discussion demonstrates how a MSC/VLR may facilitate the maintenance of different location viewpoints at different network levels. All network levels, aside from the level of the mobility management node, may continue to operate substantially as in existing procedures, unaware of the two levels of location detail managed by the mobility management node. This embodiment thus offers the greater detail of location knowledge for a mobile station with a minimum of change to procedures across network levels.

According to a third embodiment of the present invention, the mobility management node may be a BSC. According to this embodiment, the MSC/VLR may form part of the higher network levels that see only location areas, with mobile stations and basestations seeing only sub-location areas. The BSC acts as a gateway, maintaining both network views and translating between views for messages passing via the BSC. In current procedures, BSCs frequently transmit messages between a mobile station and MSC without interpreting the contents. According to the present embodiment, BSCs intercept such messages in order to translate between the sub-location area view of the mobile station and the location area view of the MSC/VLR.

Figure 11 is a flow chart illustrating process steps carried out at a BSC according to the third embodiment. In a first step 80, the BSC receives a sub-location area update request from a mobile station. It will be appreciated that, as in the case of the second embodiment, the initial update message is illustrated as a sub-LA update request because this explanation is presented from the point of view of the mobility management node, which sees both sub-LAs and LAs. From the point of view of the mobile station sending the message, the request is a location area update request. As

the mobile station is unaware of the distinction between sub-LAs and LAs, the mobile station sees all sub-LAs as LAs and initiates a location update procedure accordingly. It is only at the mobility management node that the distinction is made as to whether the change in location made by the mobile station is in fact a change of location area or
5 merely a change in sub-LA, and appropriate action is taken.

On receipt of the sub-location area update request, the BSC proceeds, at step 82 to map the new sub-LA identity in the request to its corresponding LA identity. If bit stealing is used for identifying sub-location areas, this mapping procedure may
10 comprise merely separating the sub-LA identifier into its component sub-LA and LA parts. However, if an alternative procedure, such as a hashing function is used, the mapping process may comprise applying the hashing function, or consulting a mapping table to identify the location area of which the new sub-location area forms a part.

15 At step 84, the BSC compares the new location area identity to the location area identity stored for the mobile station in the location area database. If the new and stored location area identities are the same (Yes at step 84), the BSC then determines, at step 86, whether or not the update message corresponds to a periodic location update. A periodic location update is triggered by long periods of mobile station
20 inactivity, meaning new sub-LA and LA will be the same as the stored sub-LA and LA. Periodic update messages are forwarded to the MSC/VLR and higher network levels and the process for this (Yes at step 86) is discussed further below.

If the new and stored location area identities are the same and the message is not a
25 periodic location update (No at step 86), this indicates that the mobile station has changed sub-location areas within the same location area, and a sub-location area update procedure may then be followed. In this case, the BSC proceeds at step 88 to update the sub-location area of the mobile station in its location database and to send a normal update confirmation message to the mobile station at step 90. Finally, the
30 BSC resets a timer for the mobile station entry in its database before terminating the procedure. The purpose of the database timer is discussed below.

Returning to step 84, if the new and stored location area identities are not the same (No in step 84), this indicates that the mobile station has moved into a sub-location
35 area that is part of a new location area, and a location area update procedure may then be followed. This process may also be followed when the node discovers that it has no

stored entry for the mobile station, in which case there is no stored location area identity to compare with and the comparison therefore returns a negative response. This may occur if the mobile station has newly entered the node's area of control or has powered on after a long period of power off (a period sufficiently long for the mobile station to have been purged from the database, as discussed below). In this case, the BSC still updates the sub-location area of the mobile station in the location database at step 94, creating an entry for the mobile station if necessary. The BSC then modifies the sub-location area identifier at step 96, to cause the identifier to reflect the new location area of the mobile station, obtained at step 82. Where bit stealing is used to identify sub-location areas, this modifying procedure may comprise masking the bits of the identity that correspond to the sub-location area, so that only the bits corresponding to the location area are seen. If hashing is used, this modifying process may comprise applying the hashing function or consulting a mapping table to replace the new sub-location area identity with the identity of the location area of which the new sub-location area forms a part.

Having modified the update request message to replace the sub-location area identifier with the corresponding location area identifier, the BSC then stores the new location area in its location database and forwards the update message, now in the form of a location update request, to its controlling MSC/VLR in step 98. The modified, forwarded message may in some circumstances be considered as a new message. The MSC/VLR may then proceed to perform its usual location update procedure, which may involve communication with the HLR, a former MSC/VLR etc. Having forwarded the message in step 98, the BSC creates a note on the signalling connection identifier and mobile station ID at step 100. This ensures that the BSC will be able to identify the location update response from the MSC/VLR, even if the MSC location update procedure has involved a change of identifier for the mobile station. A change in location area within the same MSC/VLR service area is often accompanied by a change in Temporary Mobile Subscriber Identity (TMSI) assigned to the mobile station, or may be accompanied by a change from International Mobile Subscriber Identity (IMSI) to a TMSI. Thus, a BSC may forward a message with a first TMSI, and receive a confirmation message with a new TMSI, or may forward a message with a IMSI, and receive a confirmation message with a TMSI. The note on the signalling connection allows the BSC to connect the forwarded message and response, even in the event of such a change.

Having created a note on the signalling connection at step 100, the BSC then resets a timer for the mobile station entry in its database at step 102 before terminating the procedure. The purpose of the database timer is discussed below.

- 5 Returning to step 86, if the BSC determines that the message received is a periodic location update message (Yes at step 86), the BSC follows the location update procedure from step 96. There is no requirement to update a new sub-LA in step 94 because the periodic location update is triggered by a long period of mobile station inactivity, thus the sub-LA and LA of the mobile station will be unchanged. The
- 10 periodic location update message is simply modified to ensure the message reflects a location area and not a sub-location area and then forwarded to the MSC/VLR according to steps 96 to 102.

- Figure 12 is a flow chart illustrating process steps carried out at a BSC according to the
- 15 third embodiment on receipt of a location update confirmation message from a serving MSC/VLR. Following the steps of Figure 11, the BSC may forward a location update request message to a MSC/VLR. Referring to Figure 12, in a first step 104, the BSC receives a location update confirmation message from the MSC/VLR. In step 106, the BSC then identifies the note on the signalling connection created at step 100 in Figure
- 20 11, allowing the confirmation message to be matched up to the forwarded location update message sent from the BSC. At step 108, the BSC determines whether the assigned mobile station identifier in the received confirmation message is the same as the mobile station identifier stored for the mobile station in the location database of the BSC. If the received and stored identifiers are the same (yes at step 108), then the
- 25 identifier assigned to the mobile station has not changed. The BSC then replaces, at step 110, the location area identifier in the received confirmation message with the new sub-location of the mobile station that was stored in the BSC location database at step 94 in Figure 11. Having inserted the new sub-location of the mobile station, the BSC forwards the confirmation message to the mobile station at step 112 and deletes the
- 30 note of the signalling connection identifier at step 114.

- Returning to step 108, if the identifier in the received confirmation message and the stored identifier for the mobile station are different (No in step 108), this signifies that a new TMSI has been allocated to the mobile station. The BSC therefore updates its
- 35 location database with this new identifier in step 116 before following substantially the same confirmation steps of replacing the location area identity in the confirmation

message with the new sub-location area of the mobile station at step 118, forwarding the message to the mobile station in step 120 and deleting the signalling connection note at step 122.

- 5 As in the second embodiment, it will be appreciated that the mobile station is unable to distinguish between an update confirmation message received following a sub-LA update procedure at step 90 in Figure 11, and an update confirmation message received following a location update procedure in steps 112 or 120 of Figure 12.
- 10 Owing to the position of a BSC within the network hierarchy, it may be required to pass other messages between a mobile station and MSC/VLR, which messages contain a location of the mobile station. According to the third embodiment, the BSC intercepts these messages to perform translation between viewpoints held by the mobile station and MSC/VLR. Figure 13 is a flow chart illustrating steps performed by a BSC
- 15 according to the third embodiment upon receipt of a message other than an update request or update confirmation.

Referring to Figure 13, in a first step 130, the BSC receives a message other than a sub-location update request or an update confirmation. If the message is being sent to

20 the mobile station, the BSC replaces, at step 132, the location area identifier in the message with the sub-location area of the mobile station, stored in the location database of the BSC. The BSC then forwards the message to the mobile station in step 134. If the message is being sent to the MSC/VLR, the BSC replaces the sub-location area in the message with the corresponding location area in step 136. This

25 may be done by masking sub-LA bits of the identity, or by hashing or reference to a mapping table. The BSC then forwards the message to the MSC/VLR in step 138 and resets a timer for the mobile station entry in its database at step 140 before terminating the procedure.

- 30 The setting of a timer for a database entry in the third embodiment has been discussed above and its purpose is now explained. It has previously been discussed that when a mobile station enters a location area under the control of a new MSC/VLR, the location update procedures involve communication with the old MSC/VLR, and cancelling the location of the mobile station in the old MSC/VLR. Thus in the first and second
- 35 embodiments, the MSC/VLR is notified when a mobile station leaves its service area, and can delete the entry for the mobile station in its location database. However, the

BSC is not involved in the cancellation process for a MS that has left the MSC service area, meaning that a BSC is not informed when a mobile station leaves the service area of its controlling MSC. In addition, there is no equivalent cancellation process when a mobile station moves into an area under the control of a new BSC. The new

5 BSC is aware of the newly arrived MS via a received location update request but the former BSC will not see the update message and thus will not know that the MS has moved to an area controlled by a new BSC. The timer entries set according the processes illustrated in Figures 11, 12 and 13 allow for a time based purge of the location database as illustrated in Figure 14, preventing the database from becoming

10 clogged with data relating to mobile stations that are no longer communicating via the BSC. According to this purge, whenever a timer for a mobile station entry in the location database reaches a threshold value, or times out, in step 150, the BSC deletes the database entry for that user in step 152. The threshold value for the timer may be set for example to be slightly longer than the threshold for a periodic location update.

15 The timer for a mobile station is reset each time a message is received from the mobile station, confirming that the mobile station is still within a location area controlled by the BSC. According to other embodiments, a location database purge may be based upon memory usage. Instead of resetting a timer on receipt of messages from mobile stations, a time stamp may be applied to the entry for the mobile station on receipt of

20 each new message from the mobile station. When a threshold amount of memory is consumed in the database, or when additional memory is needed, database entries associated with the oldest time stamps may be deleted.

The above discussion demonstrates how a BSC may facilitate the maintenance of

25 different location viewpoints at different network levels. All network levels, aside from the level of the mobility management node, may continue to operate substantially as in existing procedures, unaware of the two levels of location detail managed by the mobility management node. This embodiment thus also offers greater detail of location knowledge for a mobile station with a minimum of change to procedures across

30 network levels.

In some applications of the second or third embodiments, it may be the case that not all MSC/VLRs or BSCs may be able to handle both sub-LAs and LAs. In other examples, it may be that the identifying of sub-LAs is non systematic. In such examples, it may

35 be necessary for a HLR to supply a new serving MSC/VLR with the address of a former

serving MSCA/LR based on a complete, un-masked or un-hashed sub-location area identity.

The processes of the above described second and third embodiments may be performed under the control of a computer program which may cause a network node to execute the described process steps. Figure 15 illustrates functional units of the MSCA/LR or BSC node according to the second and third embodiments. The functional units of the node may execute the above described steps for example according to computer readable instructions received from a computer program. The MSCA/LR or BSC illustrated functions as a mobility management node 300 comprising a send/receive unit 302, an updating unit 304, a location database 306 and a paging unit 308. The location database 306 comprises a sub-location area field 306a and a location area field 306b. The node 300 further comprises a mapping unit 310, a comparison unit 312 and a modifying unit 314. If the node is a BSC, the node may further comprise a timer unit 316. It will be understood that the units of the apparatus are functional units, and may be realised in any appropriate combination of hardware and/or software.

The send/receive unit 302 is configured to send and receive messages to/from mobile stations and other network nodes. The updating unit 304 is configured to update the sub-location and location area fields of the location database according to the procedures outlines in Figures 10 and 11 to 14. The mapping unit 310 is configured to map a sub-location area identity to a location area identity. As discussed above, this may comprise separating an identity into bits corresponding to a location area and sub location area. Alternatively this may comprise applying a hashing function or consulting a look-up table. The comparison unit 312 is configured to compare a location area produced by the mapping unit 310 with a location area stored in the location database 306. The modifying unit 314 is configured to replace a sub-location area in a message with a location area, from either the mapping unit 310 of the location database 306. The modifying unit is also configured to replace a location area in a message with a sub-location area from the location database 306. The paging unit 308 is configured to manage a paging process as described below with reference to Figure 16. The timer unit 316, if present, is configured to reset a timer for a location database entry on receiving a message from the mobile station corresponding to the entry, and to delete a location database entry on expiry of the timer for that entry.

It will be appreciated that additional functional units and/or database fields may be included in the node 300 to enable the functionality discussed above. For example, the location database 306 may comprise an identity field containing either or both of a TMSI or IMSI for mobile stations whose locations are stored in the database. In addition, the node may further comprise a searching unit, operable to search the database for a particular mobile station, for example when receiving a paging request for a mobile station in order to extract the location of the mobile station from the database.

10 The above discussed embodiments illustrate how a network may manage two levels of detail concerning a location of a mobile station within a single mobility management node. As discussed above, the greater level of detail concerning the location of a mobile station may enable a more efficient paging process when it is required to locate the mobile station.

15 Figure 16 illustrates an example of a configurable paging strategy which may be employed to take advantage of the more detailed location information maintained in a network node according to the present invention. According to the paging strategy, a mobile station is first paged within its sub-location area. As discussed above, paging over this smaller area provides savings in the network resources required to support the page. If no response is received to the initial page, various repeat steps may be performed according to the status of a repeat page parameter. These steps may offer greater chance of locating the mobile station but at a greater cost in terms of the necessary network resources. If for some reason the sub-location area of a mobile station is not available, a first page may be performed in a location area, or in several location areas, if the location area of a mobile station is also not available.

With reference to Figure 16, three levels of page may be defined: a local page within a single sub-location area; a sub-global page within a location area, and a global page within all location areas of a MSC/VLR service area. Three paging parameters may also be defined, indicating actions to be taken following an unsuccessful local page (PAG-REP-SUBLA), following an unsuccessful sub-global page (PAG-REP-LA) and following an unsuccessful global page (PAG-REP-GLOB). Possible values for these paging parameters are indicated below:

35

PAG-REP-SUBLA

- (0) No repeat paging
- (1) Repeat page in sub-location area using either IMSI or TMSI
- (2) Repeat page in sub-location area using IMSI
- (3) Repeat page in location area (sub-global page) using IMSI.

5

PAG-REP-LA

- (0) No repeat paging
- (1) Repeat page in location area using either IMSI or TMSI
- (2) Repeat page in location area using IMSI
- (3) Repeat page in multiple location areas (global page) using IMSI.

10

PAG-REP-GLOB

- (0) No repeat paging
- (1) Repeat global page using IMSI

15

The definition of an unsuccessful page may be established on the basis of a time limit. If no answer is received to the page before expiry of the time limit, that stage of the paging is determined to be unsuccessful. Different time limits may be set according to whether the page is local, sub-global or global and according to whether the page is the first page of a particular type or a repeat page within the same local, sub-global or global area. Examples of possible time limits may be as follows, where FRST applies to a first page in a particular area and REP refers to repetition applying to a repeated page within a particular area:

20

- 25 PAG-TIMER-FRST-SUBLA - The time limit for a page response to a first local page (page within a sub-location area). After expiry of this time limit, repeat steps are taken according to the status of PAGREPSUBLA.

- 30 PAG-TIME-REP-SUBLA - The time limit for a page response to a repeat local page. After expiry of this time limit, the paging process is deemed unsuccessful.

PAG-TIMER-FRST-LA - The time limit for a page response to a first sub-global page (page within a location area). After expiry of this time limit, repeat steps are taken according to the status of PAGREPLA.

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PAG-TIME-REP-LA - The time limit for a page response to a repeat sub-global page. After expiry of this time limit, the paging process is deemed unsuccessful.

5 PAG-TIMER-FRST-GLOB - The time limit for a page response to a first global page (page within multiple location areas e.g. an MSC service area). After expiry of this time limit, repeat steps are taken according to the status of PAGREPGLOB.

10 PAG-TIME-REP-GLOB - The time limit for a page response to a repeat global page. After expiry of this time limit, the paging process is deemed unsuccessful.

The precise values of the above time limits (for example in seconds) may be set by a network operator according to network requirements.

15 If a repeat page parameter is set to (0), then no repeat page is performed and the paging process is deemed unsuccessful and the mobile station may be flagged as unreachable. Similarly, if no response is received to a repeat page within the relevant repeat page time limit, the paging process is deemed unsuccessful and the mobile station may be flagged as unreachable. If a response is received to a first or repeat page within the relevant time limit, paging is successful. The evolution of the paging process depends upon the status of the various repeat paging parameters, which may
20 be configured according to network requirements and priorities.

Referring to Figure 16, an example paging process is now discussed, illustrating the configurable nature of the paging strategy.

25 According to the example, a sub-location area for a mobile station to be located is known, and a first page is therefore sent within the sub-location area at step 402. The node managing the paging process checks in step 404 for an answer. If an answer is received within PAG-TIMER-FRST-SUBLA then the page has been successful. If no
30 answer is received within PAG-TIMER-FRST-SUBLA, the node checks the status of the repeat paging parameter at step 406 and conducts one of (0) no repeat page - paging unsuccessful, step 408, (1) repeat page in the sub-location area using either IMSI or TMSI, step 410, (2) repeat page in the sub-location area using IMSI, step 412, or (3) a first page in the location area of which the sub-location area forms a part, step
35 414. If a repeat page is performed at step 410 or 412 and is found to be unsuccessful (no reply within PAG-TIME-REP-SUBLA), then the paging process is deemed

unsuccessful and the mobile station is flagged as unreachable. If however, a first page in the location area is performed at step 414, then further repeat steps in the location area or MSC service area are possible in the event of no reply, depending upon the status of PAG-REP-LA.

5

It can be appreciated from Figure 16 that multiple paging processes may be conducted depending upon the availability of initial information and the status of repeat page parameters. A network operator may thus configure the paging strategy to suit network priorities, allowing escalation or close control of paging costs according to the relative
10 importance of those costs with reference to the locating of a particular mobile station.

According to embodiments of the invention, the paging process is controlled at the mobility management node having the location database with sub-location area and location area information for mobile stations. This node may be a MSC/VLR or may be
15 a BSC according to the different embodiments. The mobility management node receives a paging request for the mobile station and conducts the paging strategy substantially as described above with reference to Figure 16. In the case of a MSC/VLR, the paging request maybe received from the HLR of the mobile station. In the case of a BSC, the paging request may be received from the controlling MSC. In
20 both cases, the paging unit of the node may control the paging processes.

As indicated above, while embodiments of the present invention have been described with reference to a circuit switched GSM network, the invention may be applied to packet switched networks and to networks operating according to other standards and
25 to other generations of mobile communications technology. For example, in the case of 3G technologies, the actions and functionality described with reference to the BSC would be found/take place at the Radio Network Controller (RNC). In packet switched 2G and 3G networks, the MSC/VLR as described above would correspond to the Serving GPRS Serving Node (SGSN). In 4G technologies, the MSC/VLR and BSC
30 would correspond to the Mobility Management Entity (MME). Similarly, reference to location areas may be read as refereeing to Routing Areas, Tracking Areas or Tracking Area Lists according to the generation of the mobile network.

Also as mentioned above, while embodiments of the present invention have been
35 described with reference to sub-location areas and location areas, different correspondence relations may be envisaged between the sub-mobility areas and

mobility areas of the following claims and the location, routing and tracking areas of existing mobile communications networks.

Embodiments of the present invention thus provide a method and mobility
5 management node enabling more detailed management of mobile station locations and more efficient paging. Two levels of detail are maintained at a network node concerning the location of mobile stations. The smaller, finer grained location detail may be used for paging the mobile station, thus paging within a smaller number of cells and so reducing paging costs. In order to reduce the resource requirements of
10 managing the two levels of detail, different updating procedures may be defined for the smaller area, allowing the mobility management node to track the mobile station within the smaller areas without a significant increase in the resource cost of managing the mobile station location.

15 It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim, "a" or "an" does not exclude a plurality, and a single processor or other
20 unit may fulfil the functions of several units recited in the claims. Any reference signs in the claims shall not be construed so as to limit their scope.

CLAIMS

1. A method, in a network node, for managing a location of a mobile terminal within a mobile communications network, wherein the network comprises a plurality of mobility areas, each divided into at least one sub-mobility area, the method comprising maintaining a location database for the mobile terminal, wherein the location database indicates a mobility area and a sub-mobility area of the mobile terminal.
2. A method as claimed in claim 1, wherein maintaining a location database for the mobile terminal comprises:
 - updating a sub-mobility area of the mobile terminal in the location database when the mobile terminal enters a new sub-mobility area; and
 - updating a sub-mobility area and a mobility area of the mobile terminal in the location database when the mobile terminal enters a new mobility area.
3. A method as claimed in claim 1 or 2, wherein maintaining a location database comprises:
 - receiving a sub-mobility area update request from the mobile terminal; and
 - updating the location database with the new sub-mobility area contained in the sub-mobility area update request.
4. A method as claimed in claim 3, wherein the sub-mobility area update request comprises a Direct Transfer Application Part (DTAP) message.
5. A method as claimed in claim 3 or 4, wherein maintaining a location database further comprises:
 - mapping the new sub-mobility area to a corresponding new mobility area;
 - comparing the new mobility area to a stored mobility area for the mobile terminal in the location database; and
 - updating the mobility area of the mobile terminal in the location database if the new mobility area is different to the stored mobility area.
6. A method as claimed in claim 5, further comprising, if the new mobility area is different to the stored mobility area;
 - modifying the sub-mobility area update request to replace the new sub-mobility area with the corresponding new mobility area; and

forwarding the modified sub-mobility area update request to another network node.

7. A method as claimed in any one of the preceding claims, wherein maintaining a
5 location database comprises:
 receiving a mobility area update request from the mobile terminal;
 extracting a new sub-mobility area of the mobile terminal from the mobility area
 update request;
 updating the location database with the new sub-mobility area of the mobile
10 terminal; and
 updating the location database with the new mobility area contained in the
 mobility area update request.
8. A method as claimed in any one of the preceding claims, further comprising:
15 receiving a message from the mobile terminal containing a current sub-mobility
area of the mobile terminal;
 modifying the message to replace the sub-mobility area with a corresponding
mobility area of the mobile terminal; and
 forwarding the modified message to another network node.
- 20 9. A method as claimed in claim 8, further comprising:
 receiving a message from another network node for the mobile terminal, the
message containing the mobility area of the mobile terminal;
 retrieving from the location database the sub-mobility area of the mobile terminal;
25 modifying the message to replace the mobility area with the sub-mobility area of
the mobile terminal; and
 forwarding the message to the mobile terminal.
10. A method as claimed in any one of claims 6, 8 or 9, wherein modifying a
30 message comprises one of a bit replacement process or a hashing process.
11. A method as claimed in any one of the preceding claims, further comprising:
 paging the mobile terminal within the sub-mobility area stored for the mobile
terminal in the location database.

12. A method as claimed in claim 11, further comprising, if no reply is received to the paging in the sub-mobility area:

consulting a paging parameter for the mobile terminal; and

conducting a repeat page according to the status of the paging parameter.

5

13. A method as claimed in claim 12, wherein the repeat page comprises at least one of:

(i) a zero page in which the mobile terminal is flagged unreachable;

(ii) a sub-mobility area page;

10 (iii) a mobility area page;

(iv) a page across multiple mobility areas.

14. A method as claimed in any one of the preceding claims, wherein the mobility area comprises one of a Location Area, a Routing Area, a Tracking Area, or a Tracking Area List (TAL).

15

15. A computer program product configured, when run on a computer, to carry out a method as claimed in any one of the preceding claims.

20 16. A mobility management node in a mobile communications network, wherein the network comprises a plurality of mobility areas, each divided into at least one sub-mobility area, the node comprising a mobile terminal location database, wherein the location database comprises a mobility area field and a sub-mobility area field.

25 17. A node as claimed in claim 16, further comprising an updating unit, configured to update the sub-mobility area field and the mobility area field of the location database.

18. A node as claimed in claim 17, wherein the updating unit comprises a sub-mobility area updating sub unit and a mobility area updating sub unit.

30

19. A node as claimed in any one of claims 16 to 18, further comprising:

a mapping unit configured to map between sub-mobility areas and corresponding mobility areas; and

35 a comparison unit; configured to compare data from the mapping unit and the location database.

20. A node as claimed in claim 19 further comprising:
a modifying unit, configured to modify location data of messages processed by the node.
- 5 21. A node as claimed in any one of claims 16 to 20, further comprising:
a paging unit, configured to page a mobile terminal in a sub-mobility area.
22. A node as claimed in any one of claims 16 to 21, wherein the node comprises one of: a Mobile Switching Centre (MSC), a Base Station Controller (BSC), a Serving
10 GPRS Serving Node (SGSN), a Radio Network Controller (RNC) or a Mobility Management Entity (MME).

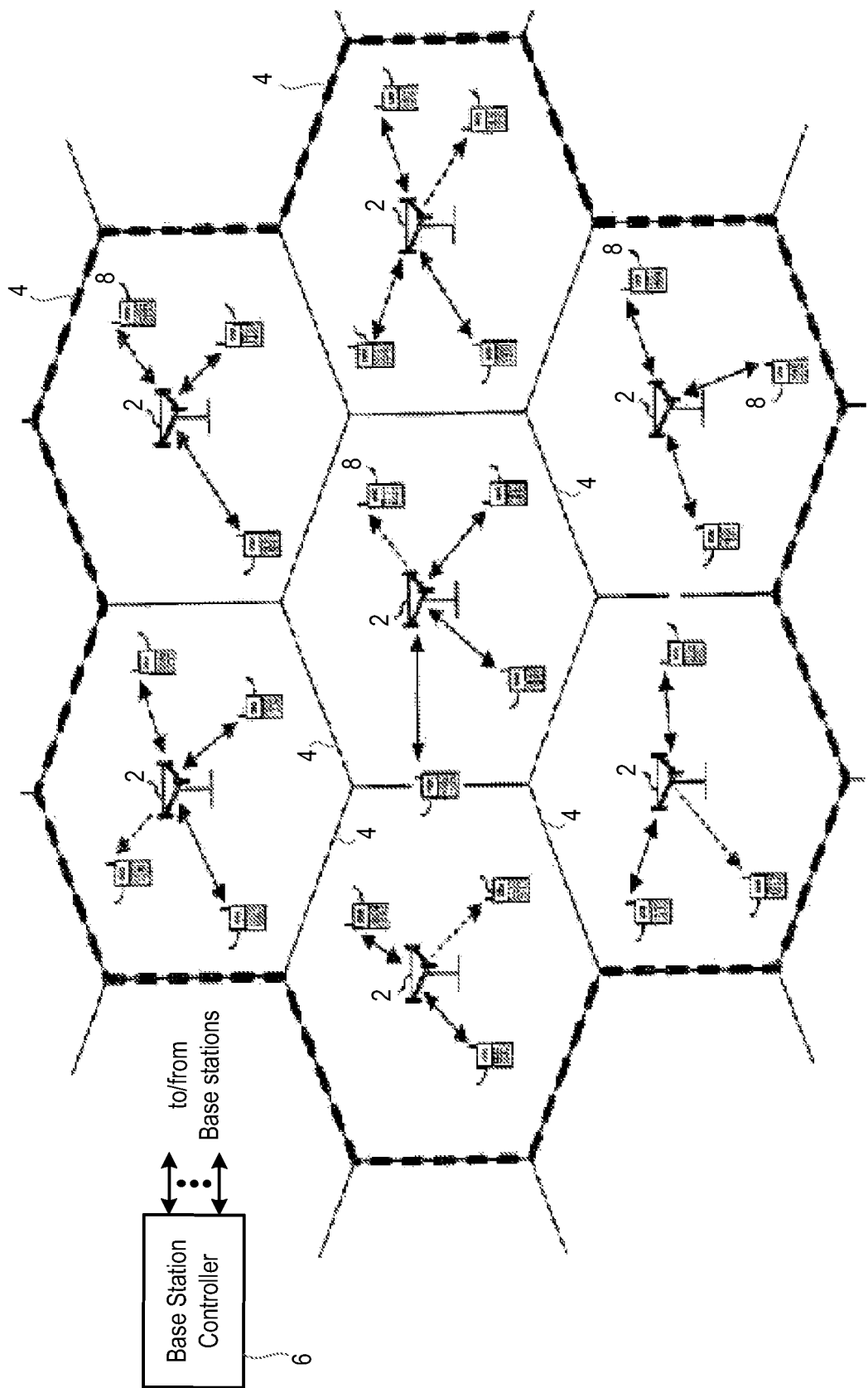


Fig. 1

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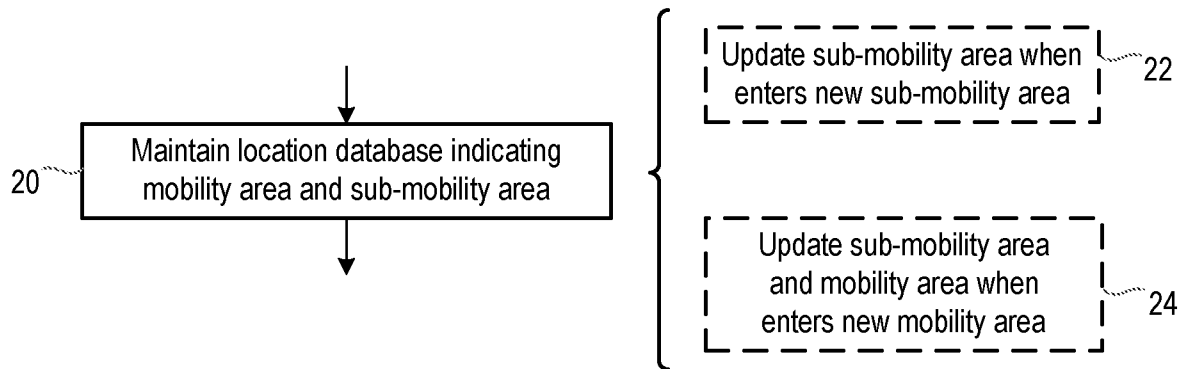


Fig. 2

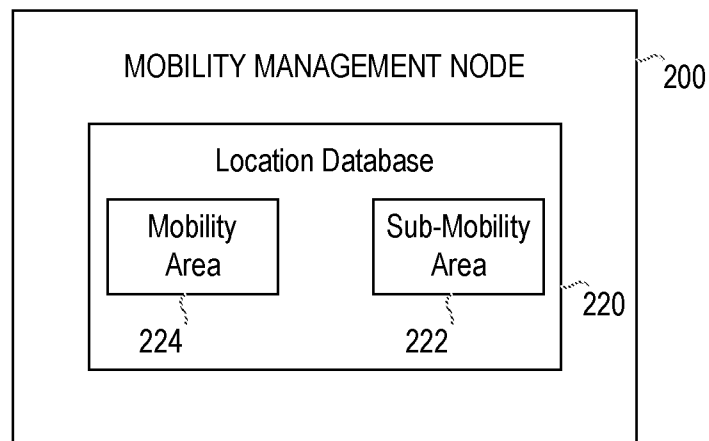


Fig. 3

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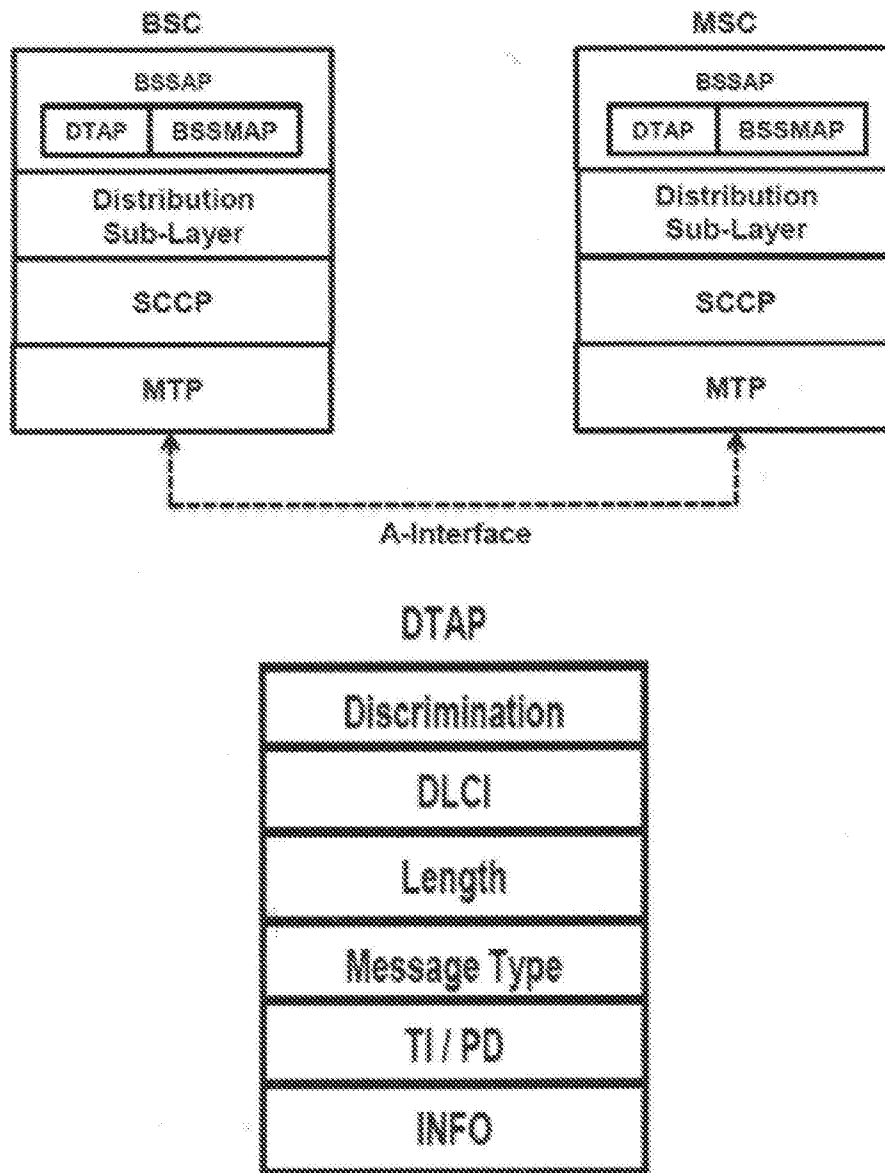


Fig. 4

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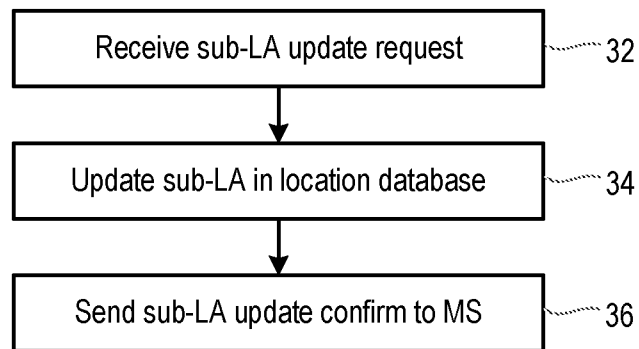


Fig. 5

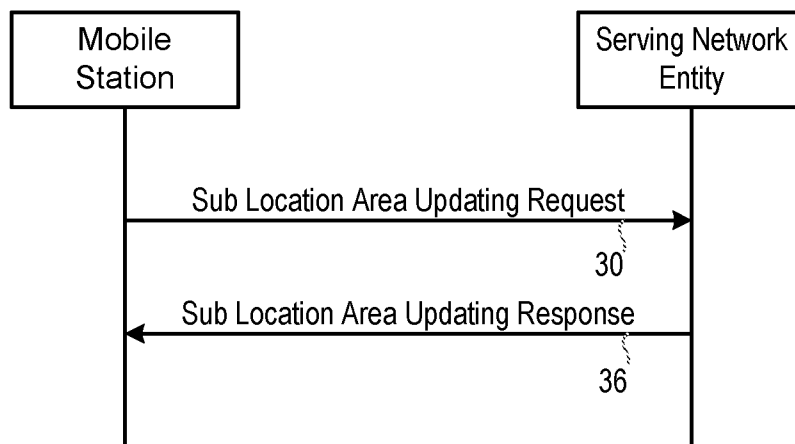


Fig. 6

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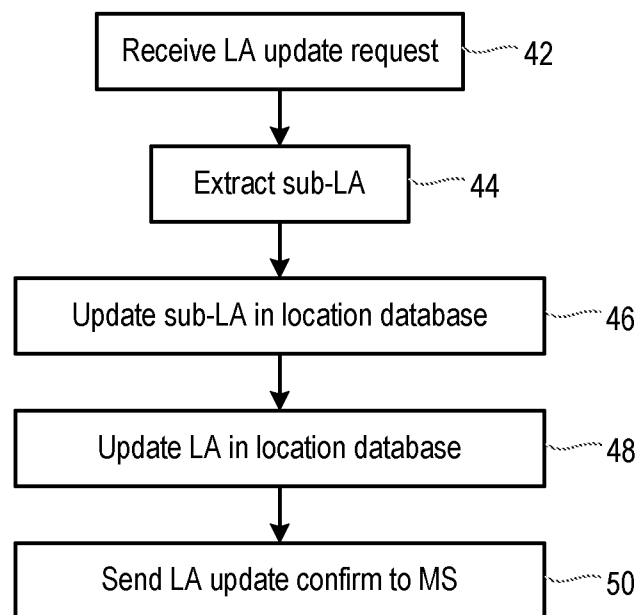


Fig. 7

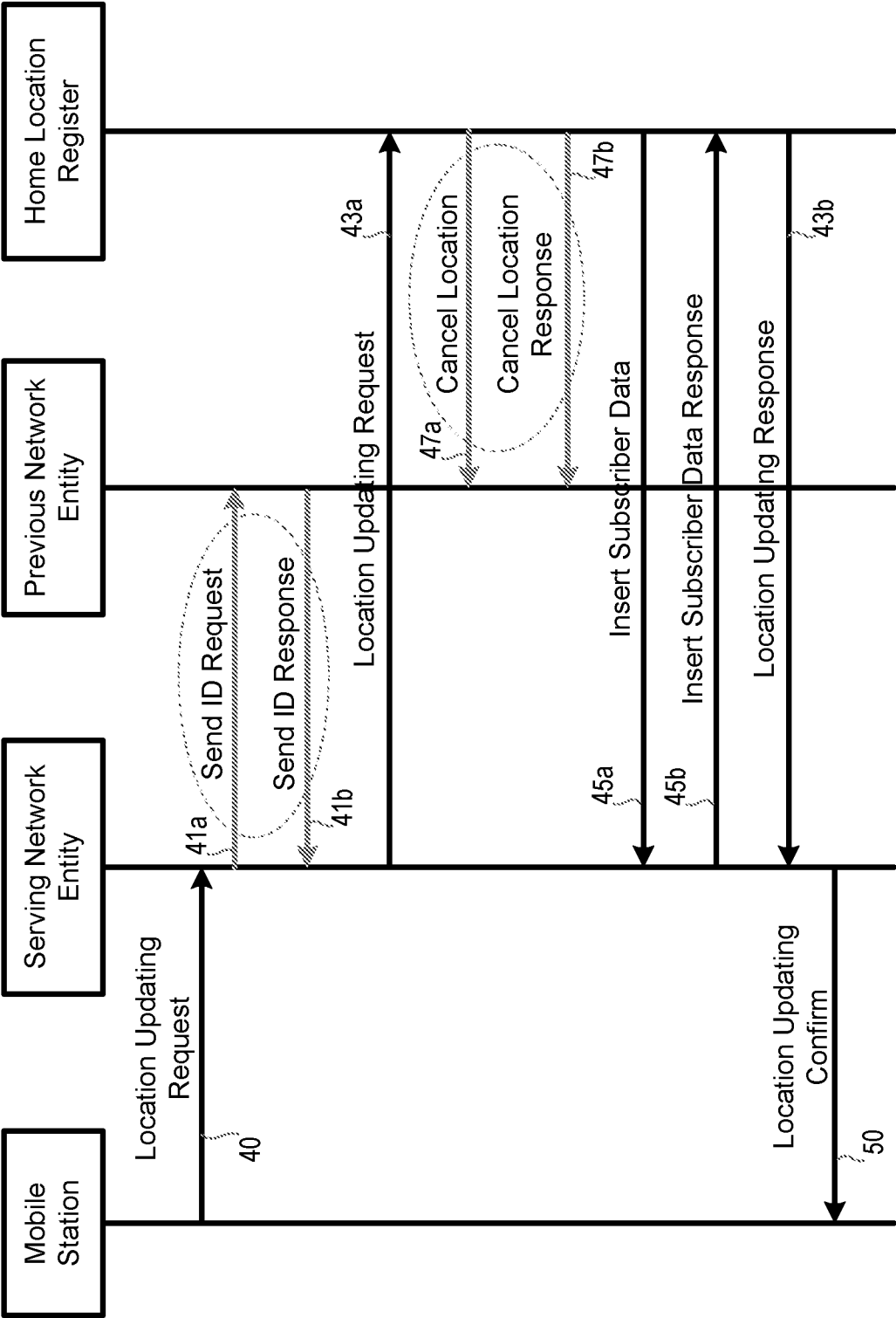


Fig. 8

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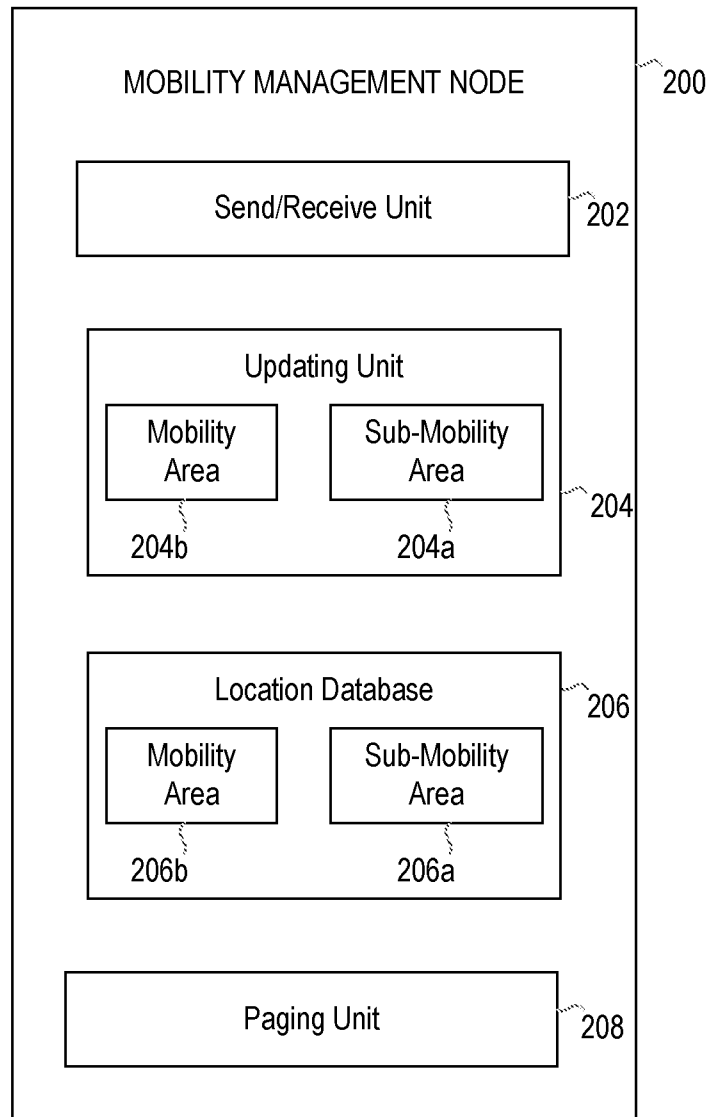


Fig. 9

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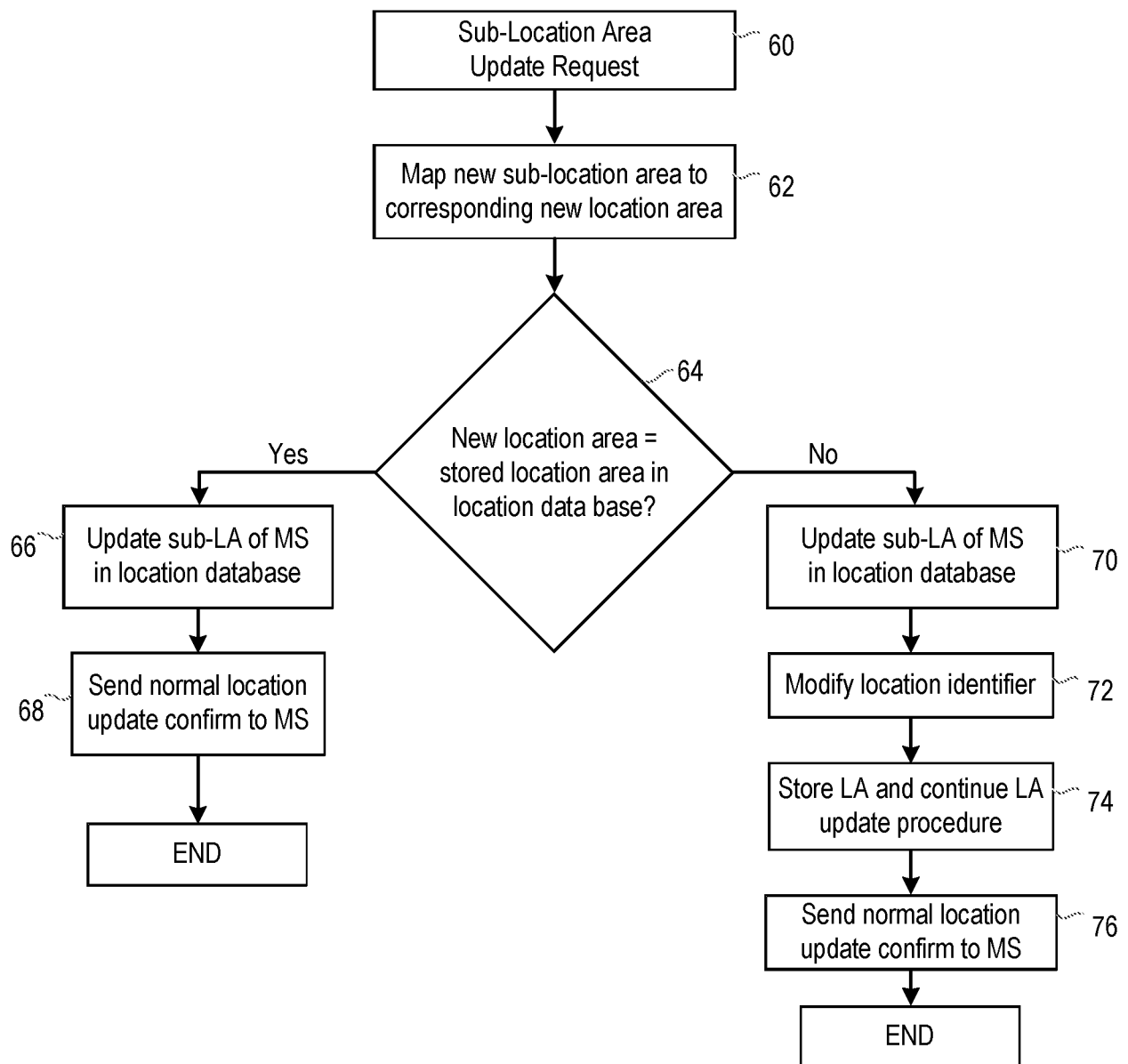


Fig. 10

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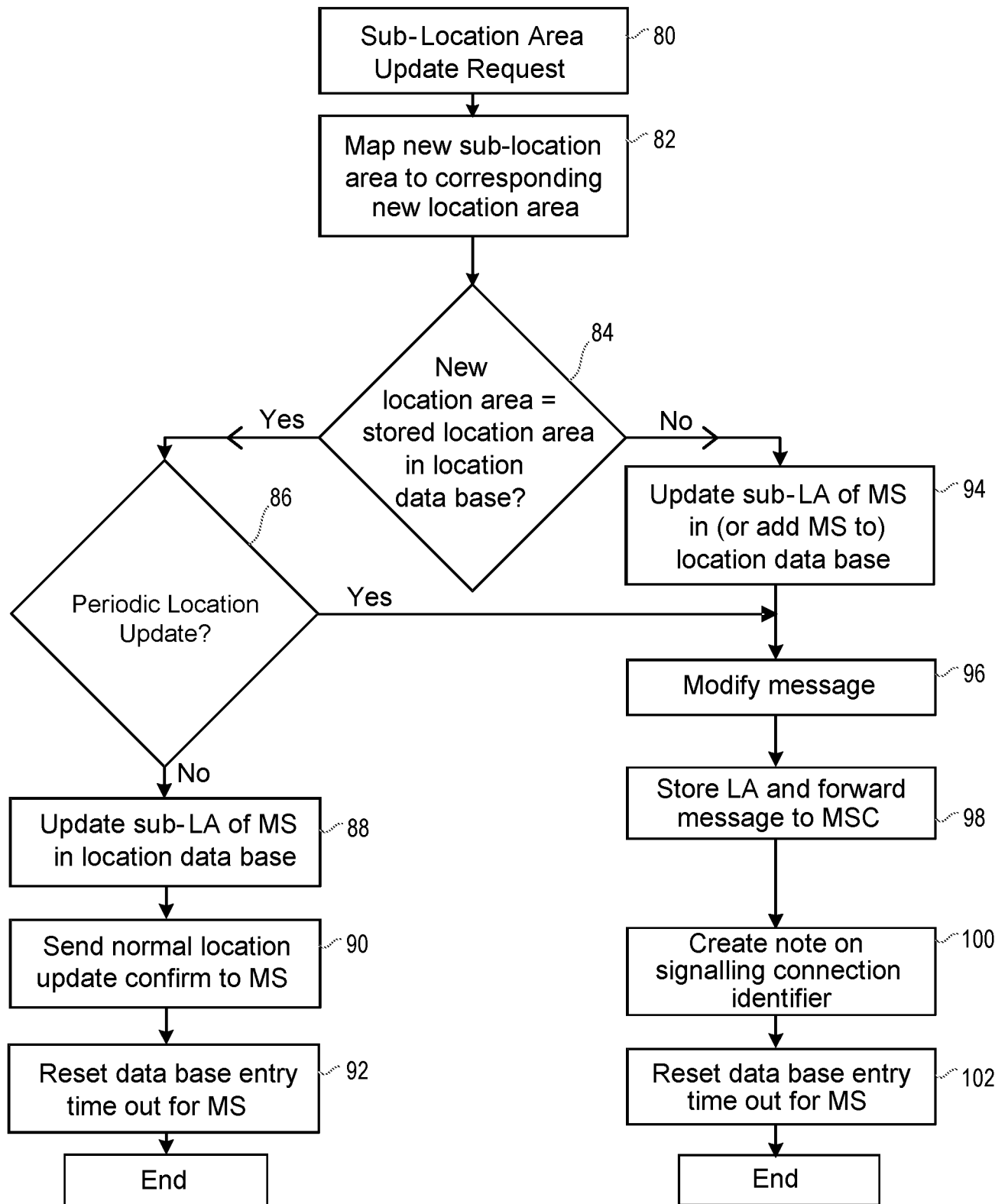


Fig. 11

10/13

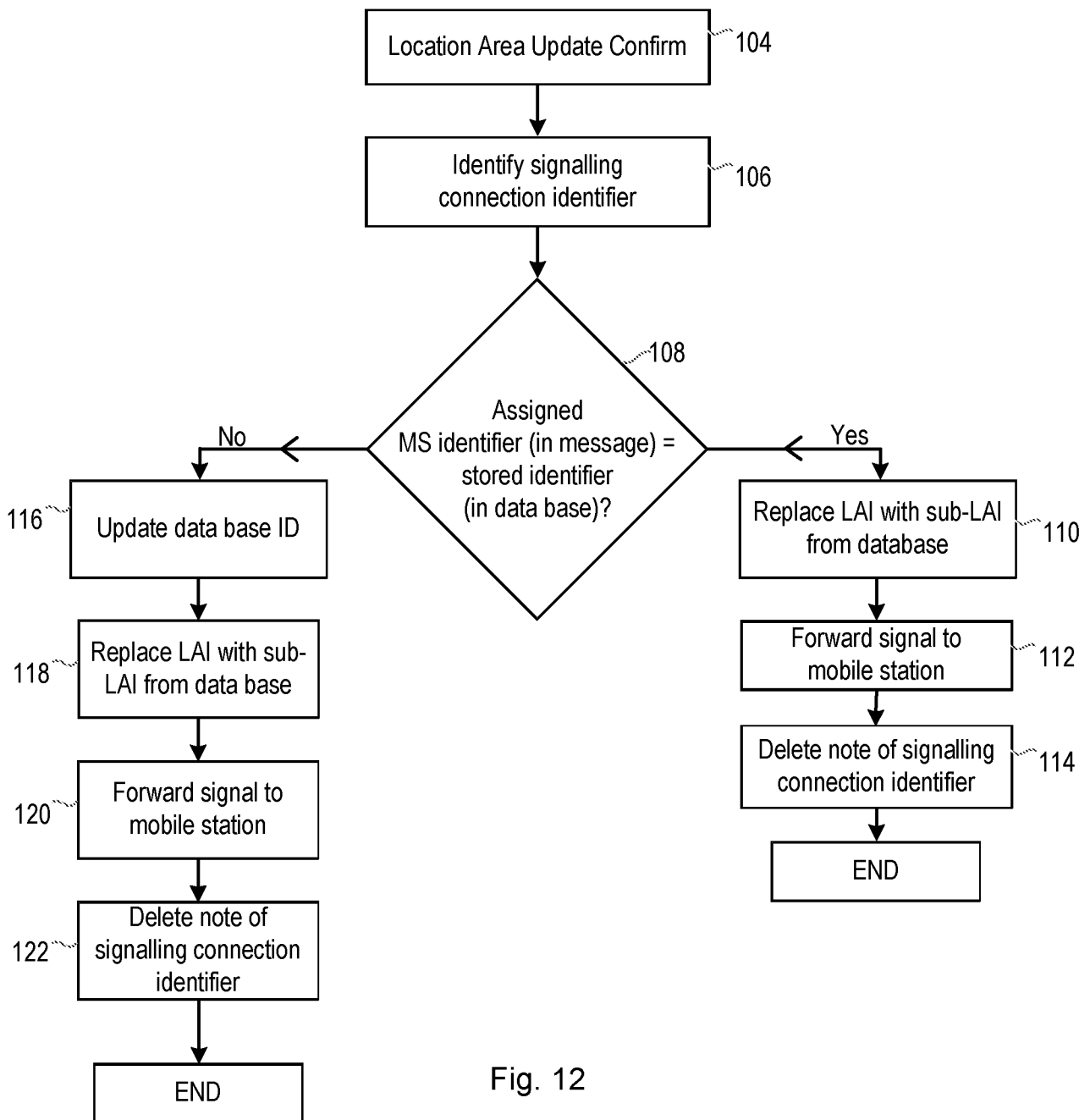


Fig. 12

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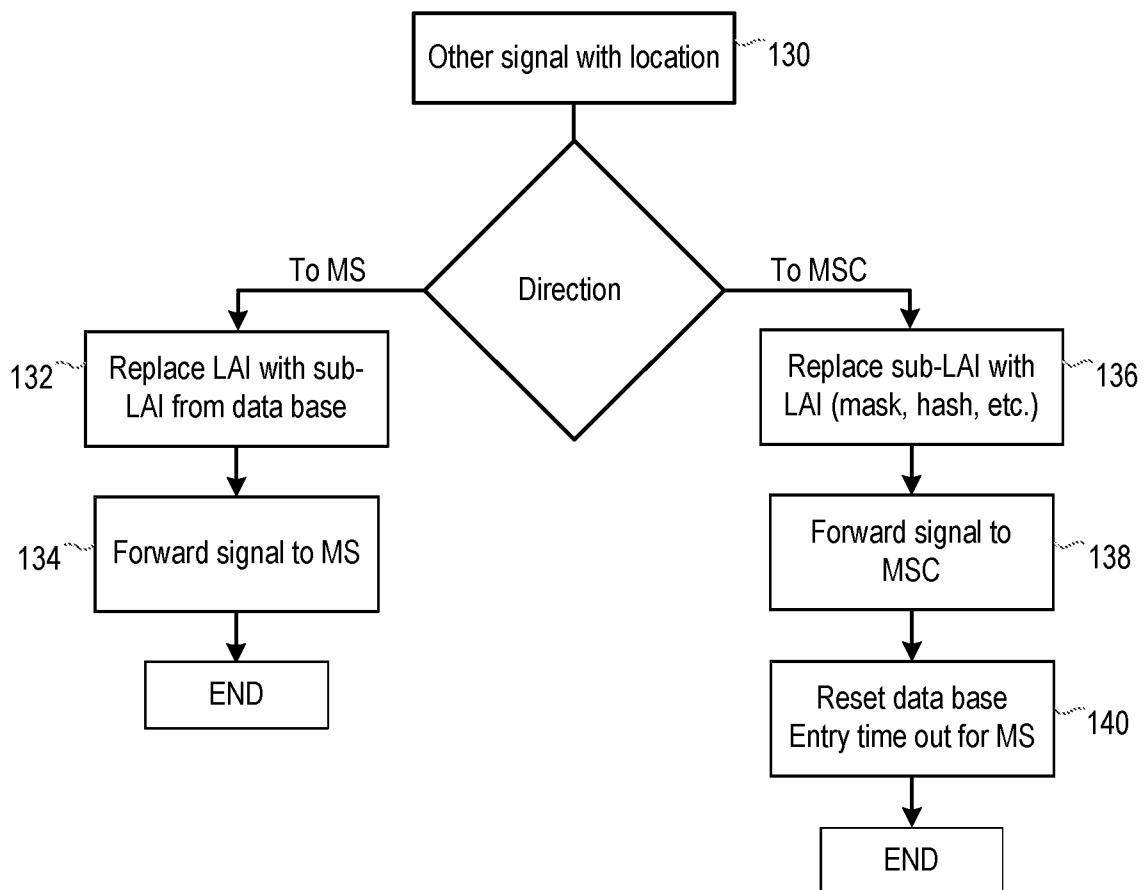


Fig. 13

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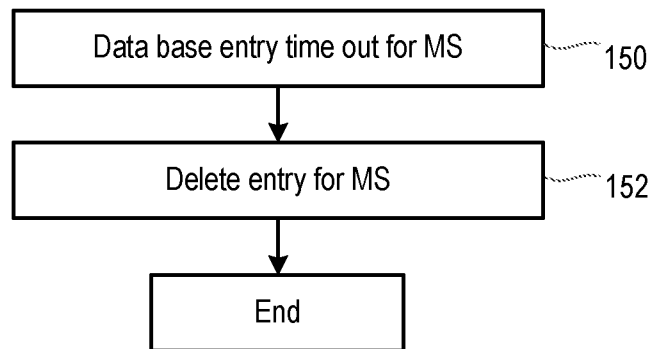


Fig. 14

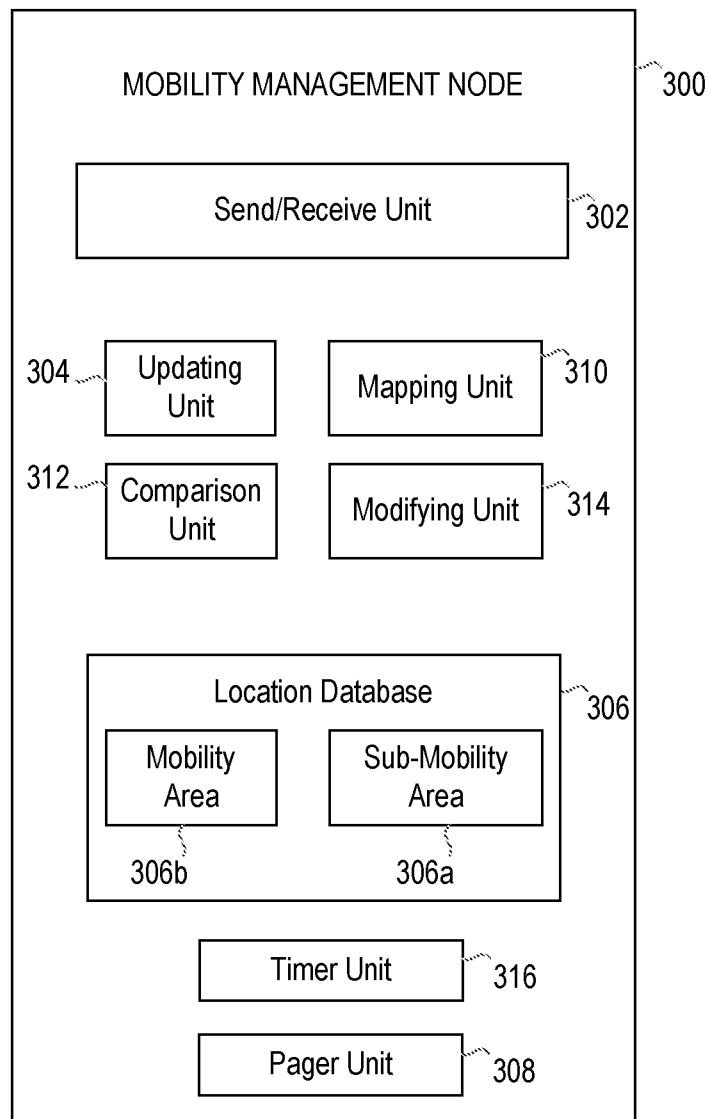


Fig. 15

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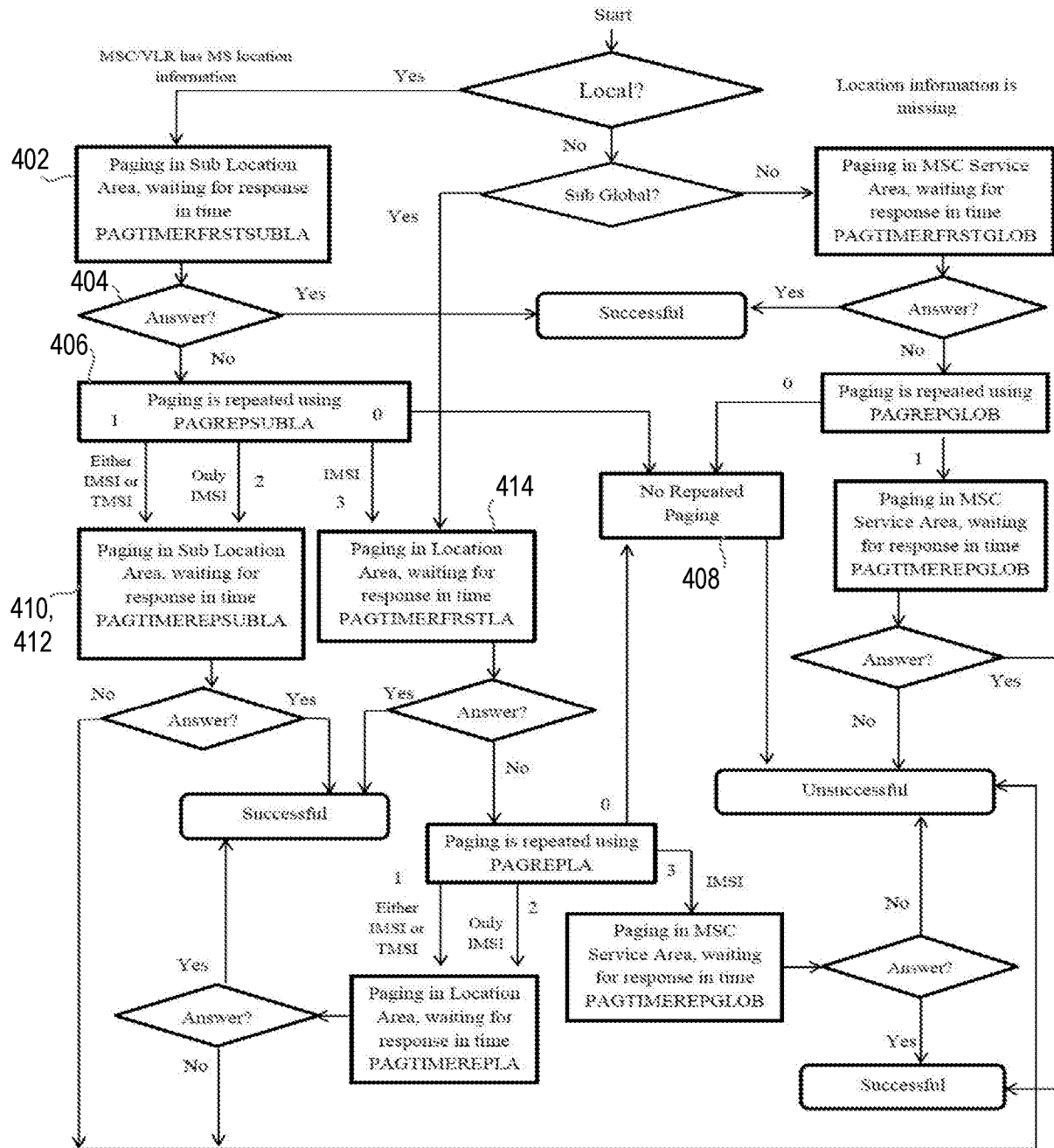


Fig. 16

INTERNATIONAL SEARCH REPORT

International application No

PCT/SE2013/050512

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W8/06

ADD. H04W68/08

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2006/217118 AI (BENCO DAVID S [US] ET AL) 28 September 2006 (2006-09-28) page 2, paragraph 15 - page 3, paragraph 21; figure 2	1-6,8-22 7
X A	EP 1 292 168 A2 (NTT DOCOMO INC [JP]) 12 March 2003 (2003-03-12) column 16, paragraph 53 - column 21, paragraph 72; figures 4-8	1,7, 15, 16 2-6, 8-14, 17-22



Further documents are listed in the continuation of Box C.



See patent family annex.

*** Special categories of cited documents :**

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

13 January 2014

Date of mailing of the international search report

20/01/2014

Name and mailing address of the ISA/

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Authorized officer

Lopez Garcia, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2013/050512

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	QUALCOMM INCORPORATED: "Paging Optimizations for Low Mobility MTC Devices", 3GPP DRAFT; S2-101026-MTC-CELL-BASED- PAGING, 3RD GENERATION PARTNERSHIP PROJECT (3GPP) , MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTI POLIS CEDEX ; FRANCE, vol . SA WG2, no. San Francisco, USA; 20100222 , 16 February 2010 (2010-02-16) , XP050433664, [retrieved on 2010-02-16] Introduction; page 1, paragraph 1 Key Issue - Low Mobility; page 2, paragraph 5.6 - page 3	1-22
A	US 2013/053072 A1 (HERBELIN PHILIPPE [FR] ET AL) 28 February 2013 (2013-02-28) page 3, paragraph 73 - page 5, paragraph 127; figure 1	1-22
A	EP 1 511 342 A1 (NTT DOCOMO INC [JP]) 2 March 2005 (2005-03-02) column 28, paragraph 96 - column 29, paragraph 100 column 58, paragraph 200 - column 59, paragraph 201	1-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2013/050512

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