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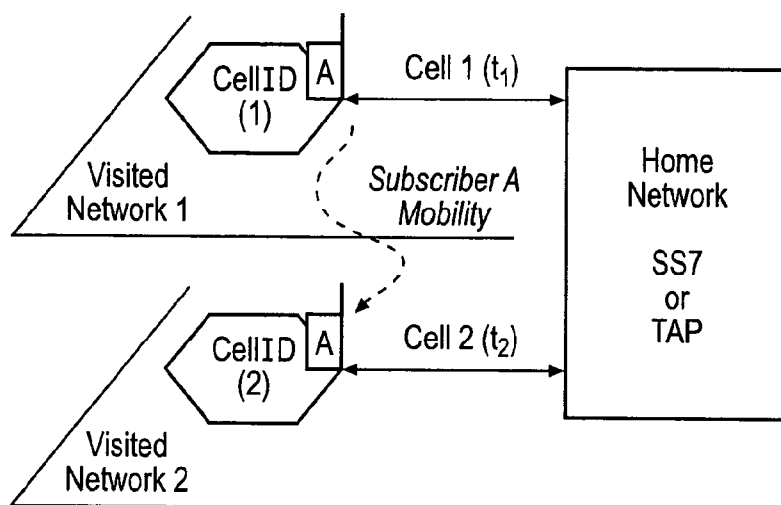
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(54) Title: APPARATUS AND METHOD TO IDENTIFY THE LOCATION OF A RADIO CELL



(57) Abstract: A telecommunications system provides a facility for mobile nodes to communicate via one or more mobile radio networks. A data processor is provided which is operable to detect a communication from a mobile node via a first radio-coverage cell at a first time, and to detect a communication from the mobile node via a second radio-coverage cell at a second time. The data processor is then operable to determine that the difference between the second time and the first time is less than a predetermined value, and if so to identify the location of the first radio-coverage cell based on knowledge of the location of the second radio-coverage cell. In this

way, communications made within a predetermined time of each other on the same mobile terminal but via different radio-coverage cells can be used to identify the location of one of those radio-coverage cells from the known location of the other of the radio-coverage cells.

APPARATUS AND METHOD TO IDENTIFY THE LOCATION OF A RADIO CELL

Field of the Invention

The present invention relates to a telecommunications apparatus and method for identifying a geographical location of radio-coverage cells within a mobile access
5 network.

The present invention also relates to a telecommunications apparatus and method for identifying network traffic associated with a transport route.

Background of the Invention

10 In a mobile network environment, such as a GSM (Global System for Mobile communications) network environment, radio coverage is an important factor. The more extensive the radio coverage provided by a mobile radio network, the greater the likelihood that a mobile node will select that mobile radio network for attachment and for providing a communications session. To some degree an operator can determine
15 weaknesses in their own mobile radio network based on a detailed knowledge of the location of network components, and in particular radio transceivers, within the mobile radio network and also based on the topography of the country or region in which the mobile radio network exists. However, in order to increase the likelihood of capturing inbound roamers, the radio coverage provided by the mobile radio network should be
20 increased relative to the radio coverage provided by competing mobile radio networks. While the operator of a mobile radio network will have access to detailed information about the radio coverage in his own mobile radio network, he will not have access to such detailed information in respect of the radio coverage provided by competing mobile radio networks.

25

Summary of Invention

According to an aspect of the present invention, a telecommunications system provides a facility for mobile nodes to communicate via one or more mobile radio networks. The telecommunications system comprises a data processor which is
30 operable to detect a communication from a mobile node via a first radio-coverage cell at a first time and to detect a communication from the mobile node via a second radio-

coverage cell at a second time. The data processor is then able to determine that the difference between the second time and the first time is less than a predetermined value, and if so to identify the location of the first radio-coverage cell based on knowledge of the location of the second radio-coverage cell.

5 In this way, communications made within a predetermined time of each other on the same mobile node but via different radio-coverage cells can be used to identify the location of one of those radio-coverage cells from the known location of the other of the radio-coverage cells.

 The identity of the radio-coverage cells used to support the communications
10 session could be provided from the visited network to the home network as signalling messages, for instance SS7 (Signalling System No. 7) signalling messages, produced as a result of the communications session, or could alternatively be provided from the visited network to the home network in the form of a Transferred Account Procedure (TAP) file communicated from the home network to the visited network as part of the
15 billing procedure in respect of the communications session.

 The indication of the identity of the cell may be provided to the home network as a result of a communications session which is provided to the mobile node by the visited mobile access network and may indicate the cell to which the mobile node was affiliated during that communications session. In this case, the received indication of
20 the geographical location associated with the mobile node will be received from the home network and will include a geographical location of a known radio-coverage cell to which the mobile node was affiliated during a further communications session provided to the mobile node within a predetermined time period before or after the communications session during which the mobile node was affiliated with the
25 unknown radio-coverage cell.

 In this way, a network operator is able to use mobile nodes subscribed to his own network or a partner network, to analyse the radio coverage of a competing mobile access network. In particular, the locations of radio-coverage cells within competing networks can be identified and used to enable the analysis of the competing
30 network on a network-wide or regional basis.

 In some embodiments, the estimate of the location of a cell may be improved by identifying communications made on a cell with an unknown location within a

predetermined time of a plurality of communications made on known cells. By determining a plurality of estimated geographical locations for the unknown radio cell from a corresponding plurality of known radio-coverage cells, and by calculating an average of the estimated geographical locations for the unknown radio-coverage cell,
5 an improved estimated geographical location for the unknown radio-coverage cell can be generated.

According to another aspect of the invention, a telecommunications system provides a facility for mobile nodes to communicate via one or more mobile radio networks, the mobile nodes being subscribed to a home network and visiting a visited
10 network. The telecommunications system comprises a data processing apparatus which is operable to detect a first area update message which is generated when a mobile node subscribed to the home network becomes affiliated to a radio-coverage cell associated with one of a first predetermined list of visitor location registers and which is communicated to the home location register of the home network of the
15 mobile node, the first predetermined list of visitor location registers being associated with a first location. The data processing apparatus is also operable to detect a second area update message which is generated when the mobile node becomes affiliated to a radio-coverage cell associated with one of a second predetermined list of visitor location registers and which is communicated to the home location register of the
20 home network, the second predetermined list of visitor location registers being associated with a second location. Based on the two area update messages, the data processing apparatus is able to determine a time difference between the generation of the first area update message and the generation of the second area update message and to identify whether the mobile node is associated with a particular route or region
25 in accordance with the determined time difference.

In this way, it is possible to identify, for example, a market segment of a transport route corresponding to those mobile nodes which transit between two predetermined locations, associated with the first and second visitor location registers, as would be the case for instance for passengers using mobile terminals and travelling
30 on the same train, road, boat or aircraft trip. The market share for multiple operators can then be analysed in respect of the train, road, boat, airport or region segment. In another example a market share for a particular region can be determined by arranging

for the first and the second visitor location registers to correspond with a region or vicinity of interest.

Various further aspects and features of the present invention are defined in the appended claims.

5

Brief Description of the Drawings

Embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings where like parts are provided with corresponding reference numerals and in which:

10 Figure 1 schematically illustrates a telecommunications system operating in accordance with a first embodiment of the invention;

Figure 2 schematically illustrates a telecommunications system operating in accordance with a second embodiment of the invention;

15 Figure 3 schematically illustrates the handover of a mobile node between multiple visited networks;

Figure 4 schematically illustrates a method of determining adjacent radio-coverage cells;

Figure 5 schematically illustrates a method of locating a radio-coverage cell having an unknown location using the known locations of adjacent cells;

20 Figure 6 is a schematic flow diagram of a radio-coverage cell locating method according to the first embodiment of the invention;

Figure 7 schematically illustrates a telecommunications system in which a location-based method of locating radio-coverage cells having an unknown location is used;

25 Figure 8 schematically illustrates the location-based method of locating radio-coverage cells used in the telecommunications system of Figure 7;

Figure 9 schematically illustrates the hierarchical radio-coverage structure of radio-coverage cells, location areas and visitor location registers;

30 Figure 10 is a table which illustrates an example count of VLRs, LACs and Cell Ids for multiple radio networks;

Figure 11 schematically illustrates a method of determining market share for mobile nodes transiting via train between two locations in accordance with an embodiment of the invention;

Figure 12 schematically illustrates an example train route to which the market share determination method of Figure 11 can be applied;

Figure 13 is a schematic flow diagram of a market share determination method for in-transit mobile nodes;

Figure 14 schematically illustrates a correspondence between a train time schedule and the number of users using VLRs associated with the train market segment;

Figure 15 schematically illustrates a distribution of times for users to transit between VLR IN and VLR OUT;

Figure 16 is a table which illustrates an example market share comparison for three mobile operators which operator in the determined train market segment;

Figure 17 schematically illustrates a loss-cell detection method in accordance with an embodiment of the invention; and

Figure 18 schematically illustrates a method of determining market share for mobile nodes entering an airport via an aircraft.

Description of the Example Embodiments

Example embodiments of the present invention will now be described with reference to the example of a Global System for Mobiles (GSM), although it will be appreciated that the embodiments of the present invention find application with other mobile telecommunications networks and standards.

Figure 1 provides an example schematic block diagram of a mobile radio network according to the Global System for Mobiles (GSM) standard. In Figure 1 a mobile switching centre (MSC) is connected to a plurality of base station controllers (BSC). Each of the base station controllers are connected to a plurality of base transceiver stations (BTS). The base transceiver stations and the base station controllers to which they are connected form base station sub-systems. Data is communicated via an air interface in accordance with the GSM standard between mobile nodes MN and one of the base transceiver stations with which the mobile node

MN is currently affiliated via radio signals. While a mobile node MN is within a coverage area 2, 4, 6 provided by a base transceiver station, radio communications are available through that base transceiver station for transmitting and receiving data via the air interface.

5 Also forming part of the GSM network shown in Figure 1 is a visitor location register (VLR) which maintains a current location of each mobile subscriber which has roamed to the mobile network as a visited network. The VLR provides an indication of which of the base stations or group of base stations a mobile node MN is currently affiliated with. The GSM network also includes a home location register (HLR) which
10 stores information specific to each subscriber to the mobile network which forms the home network for that subscriber. For example the HLR will store an indication of a visited mobile network to which a mobile subscriber has roamed, including an indication of the VLR of the visited network. The HLR also has access to an equipment identity register (EIR) to provide a facility through which a network
15 operator may track stolen or malfunctioning terminals. The HLR also includes an authentication centre (AUC) which is used to store information associated with security features provided by the network.

The mobile switching centre is connected to a gateway MSC (MSC_GW) which provides a facility for connecting the mobile switching centre to other
20 telecommunications networks which may include a public switched telephone network. An MSC support function (SUPP_FUNC) is also connected to the gateway MSC. More details on the GSM network may be found in a publication entitled "GSM, CDMA1 and 3G systems" by R. Steel ET AL published by Willie ISBN 0471491853.

25 Although Figure 1 provides an example of a second generation GSM network, it will be appreciated that embodiments of the present invention find application with other types of mobile networks such as for example 2.5G and 3G operating in accordance with the Universal Mobile Telecommunications System (UMTS).

30 Additionally, embodiments of the present invention may also find application with networks using other radio access technologies, such as a Wireless Local Area Network (WLAN). With WLAN for example, the SS7 signalling used in respect of

the GSM network to determine Cell ID is replaced with Radius signalling, and the TAP file becomes a Radius CDR.

A mobile node which has roamed to a network other than its home network may select a visited mobile network either automatically or manually. In manual
5 mode the user is presented with a list of available networks and invited to choose a preferred network. In an automatic mode, the user equipment may use a set of rules to find an appropriate network to visit. These rules may be included in the Subscriber Identity Module (SIM) card of the user equipment and may be used to ensure that a roaming subscriber visits a network preferred by the operator of the subscriber's home
10 network in preference to a non-preferred network.

In Figure 1 a Signalling Transfer Point (STP) 12 provides a concentration point for signalling communications between the mobile radio network and other networks. Attached to the STP 12 is a signalling capture device 14, which detects signalling data communicated to and from the STP 12. The signalling data may be SS7 signalling
15 data and includes signalling messages communicated for example, to and from the MSC, the VLR, and the HLR of the mobile network. As will be explained shortly the signalling data captured by the signalling capture device 14 is used to detect calls made on a visited mobile network. The detection of the call may be made by identifying an event where a mobile subscriber initiates a mobile originated call or
20 receives a mobile terminating call via the visited mobile network. For instance, a mobile originated call will trigger the communication of service signalling data associated with a CAMEL signalling communication such as a CAMEL Application Part (CAP) Initial Detection Point (IDP). The CAP IDP identifies the mobile node from the International Mobile Subscriber Identifier (IMSI), a cell (Cell ID) of the
25 visited network from which communication was made and the VLR of the visited mobile network.

The CAP IDP message can therefore be intercepted by the signal capture device 14 and passed to a data processor 10, thereby providing the data processor 10 with a Cell ID indicating a radio-coverage cell within the visited network at which the
30 mobile node is located and via which the mobile node is communicating. The data processor 10 is also arranged to access a database (DB) 25 which stores the geographical location of a plurality of radio-coverage cells within one or more mobile

access networks. The geographical locations are stored in the database in association with the Cell ID of the radio-coverage cells to which the geographical locations correspond. The radio-coverage cells within the database 25 may be radio-coverage cells of a mobile network which is affiliated in some way with the home network, such that the home network is permitted to know the locations of the radio-coverage cells. Alternatively, or even additionally, the database may include radio-coverage cells from a non-affiliated network which have been identified and located by this or another method.

The data processor 10 is able to query the database 25 for a geographical location associated with a particular Cell ID. If the data processor 10 detects signalling relating to two calls made to or from the same mobile terminal on different radio-coverage cells within a predetermined maximum time separation from each other, the data processor 10 is able to make an assumption that the different radio-coverage cells are "adjacent" cells. This is because it is considered unlikely that the mobile terminal could have moved a substantial distance within that predetermined maximum time separation. For example, the maximum time separation could be selected as 15 minutes. Using this assumption, and by referring to the database 25, if the radio-coverage cell used to make one of the calls is at a known geographical location, by virtue of it being present within the database 25, then the radio-coverage cell used to make the other call can be attributed an estimated geographical location which is based on the known geographical location of the radio-coverage cell at the known location.

The longer a time window within which calls are counted, the greater the number of calls which will be included in the time window and therefore the greater the statistical sample which can be used to identify the geographical locations of cells having an unknown location. However, given that the speed of the mobile is unknown, the greater the time window within which results are counted, the less accurate the estimate of the geographical location of the cell will be. Accordingly, the time window should be selected to balance these competing factors.

In Figure 1, the Cell ID is identified from SS7 signalling data exchanged between the MSC, VLR and HLR. Figure 2 schematically illustrates an alternative network arrangement in which the Cell ID is identified from a Transaction Application

Part (TAP) file which is generated by a visited network and sent to the home network of a visiting mobile node in order to effect billing in respect of a communications session. In Figure, 2, a mobile node (MN) 31 is currently visiting and affiliated to a Visited Public Land Mobile Network (VPLMN) 30. For example, the mobile node 31
5 may have roamed to the VPLMN 30 or handed over to the VPLMN 30. The mobile node 31 is in radio communication with the VPLMN 30 via a Base Transceiver Station (BTS) 32. Communications between the mobile node 31 and the VPLMN 30 are carried out under the control of a Base Station Controller (BSC) 33. The present invention is not limited to any particular type of communications session or radio
10 access technology, and could function in respect of, for instance, a voice call, instant or video messaging, or data streaming. For the sake of clarity, the following example is based upon a voice call made to or from the mobile node 31. A Mobile Switching Centre (MSC) 34 is provided and operates to exchange information with location databases such as the Visitor Location Register (VLR) 37 of the VPLMN 30. The
15 VLR 37 is operable to communicate subscriber data to and from a Home Location Register (HLR) 41 of the mobile node 31 in a Home Public Land Mobile Network (HPLMN) 40 of the mobile subscriber 31.

The MSC 34 communicates with a Call Detail Record (CDR) Unit 35 which generates a Call Detail Record which includes billing information. In particular, the
20 CDR may contain details such as the called and calling parties, call length, time of day and an indication of the identity (Cell ID) of a radio-coverage cell with which the mobile node 31 was affiliated when the call was made. The radio-coverage cell may be the geographical area covered by the BTS 32. The Call Detail Record is then passed to an external party, known as a Data Clearing House (DCH) 36 which
25 generates a Transferred Account Procedure (TAP) file which can be communicated to a billing system 42 of the HPLMN 40 of the mobile node 31.

A data processor 10' is provided and is arranged to extract Cell ID information and call time information from the TAP file sent from the Data Clearing House 36 to the billing system 42. For instance, a probe could be provided within the HPLMN 40
30 to intercept the TAP file before it is received by the billing system 42, or alternatively the billing system 42 could be operable on request from the data processor 10' to communicate the TAP file, or at least the relevant data from the TAP file, to the data

processor 10'. The data processor 10' is also arranged to access a database (DB) 43, which may be provided within the HPLMN 40, or which may be stored within the data processor 10' itself, and which stores the geographical location of radio-coverage cells within one or more mobile access networks. The data processor 10' is operable to
5 query the database 43 for a geographical location associated with a particular Cell ID. If the data processor 10' identifies data relating to two or more calls made to or from the same mobile terminal on different radio-coverage cells within a predetermined maximum time separation from each other, the data processor 10' will determine the radio-coverage cells to be "adjacent" cells. If one of these radio-coverage cells is at a
10 known location and the other is at an unknown location, the geographical location of the radio-coverage cell for which the location is unknown can be estimated from the geographical location of the radio-coverage cell for which the location is known.

Figure 3 schematically illustrates how a mobile node may change affiliation between multiple visited networks as it moves throughout a geographical area. A
15 mobile node may change affiliation between radio-coverage cells within the same radio network, or between radio-coverage cells of different radio networks. A change of affiliation may result when the radio-signal quality provided by a current radio-coverage cell reduces compared with the radio-signal quality provided by an adjacent radio-coverage cell. In the example of Figure 3, radio-coverage cells associated with
20 two different radio networks are shown. In particular, a first radio network is represented by an MSC 320, which controls a BSC 332, a BSC 334 and BSC 336. The BSC 332 controls a BTS 342, the BSC 334 controls a BTS 344 and the BSC 336 controls a BTS 346. A second radio network is represented by an MSC 350, which controls a BSC 362 and a BSC 364. The BSC 362 controls a BTS 372 and a BTS 374.
25 The BSC 364 controls a BTS 376. Each BTS within the first and second radio networks provides a corresponding radio-coverage area which is represented in Figure 3 by an ellipse surrounding the respective BTS.

The movement of a mobile node 310 across several radio-coverage cells is illustrated in Figure 3, with the position of the mobile node 310 at four different times,
30 t , t' , t'' and t''' . At the times t , the mobile node 310 is present within a radio-coverage area provided by the BTS 372 of the second visited network, and is therefore affiliated with the second visited network. A communications session provided to the mobile

node at the time t will therefore use the second visited network. At the time t' the mobile node 310 is within a radio-coverage area of both the BTS 372 of the second visited network and the BTS 344 of the first visited network. If it is determined that the radio-signal quality provided by the BTS 344 is better than the radio-signal quality provided by the BTS 372, a procedure for changing affiliation from the second visited network to the first visited network will commence. The procedure for changing affiliation between radio coverage cells of different visited radio networks involves an exchange of signalling between the mobile node 310 and the first and/or second visited network, and also involves communicating a location update message to the home location register within the home network of the mobile node, such that the home network is able to route incoming calls to the correct visited mobile radio network.

At the time t'' , the mobile node is within the radio-coverage area of both the BTS 344 of the first visited network and the BTS 376 of the second visited network, and may therefore change affiliation from the first to the second visited network as described above. Then, as the mobile node moves through the radio-coverage area of the BTS 376 of the second visited network until a time t''' , it will remain affiliated with the BTS 376.

It will therefore be appreciated that a mobile node may be required to switch between different radio-coverage cells on different mobile radio networks in order to maintain a radio communications link. In the case of a mobile node which is within its home network, the mobile node will usually remain attached to the home network in preference to any other network. In the case of a mobile node which is roaming outside of its home network into a visited network, the mobile node may attach to the visited network which will provide the best radio signal quality, but may also take other factors into account, such as a list of preferred networks provided within a Subscriber Identity Module (SIM) of the mobile node. The operator of each of the visited mobile radio networks seeks to increase the amount of time that an inbound roaming mobile node spends on their own network, because revenue is generated when a mobile node makes a call on a visited mobile radio network.

Figure 4 is a schematic illustration of a method of estimating a geographical location of a radio-coverage cell having an unknown location from a call made on an adjacent radio-coverage cell. In Figure 4, a first call (Call 1) is made on a radio-

coverage cell having a Cell ID "1" on a first visited network (Visited Network 1) either to or from a mobile node A at a time t_1 . As a result of this call, a TAP file and SS7 signalling will be transmitted to the home network of the mobile node A. One or both of the TAP file and SS7 signalling can be used to determine the time t_1 of Call 1 and the Cell ID of the radio-coverage cell to which mobile node A was affiliated at the time of Call 1. Following Call 1, mobile node A moves into the coverage area of a radio-coverage cell having a Cell ID "2" on a second visited network (Visited Network 2), and a second call (Call 2) is then made, at a time t_2 , to or from the mobile node A. As with Call 1, a TAP file and SS7 signalling are transmitted to the home network of the mobile node A, and can be used to determine the time t_2 of Call 2 and the Cell ID of the radio-coverage cell to which mobile node A was affiliated at the time of Call 2. In this case, $t_2 - t_1 < T_{\max}$, $T_{\max}$ being the maximum time separation, and so the radio-coverage cell having the Cell ID "1" and the radio-coverage cell having the Cell ID "2" are considered to be adjacent cells.

If the geographical location of one these adjacent cells is known, but the geographical location of the other is not known, then an assumption can be made that the geographical location of the cell having an unknown location is close to the geographical location of the cell having a known location as a result of the time $t_2 - t_1$ between Call 1 and Call 2 being less than $T_{\max}$. As will be exemplified by Figure 5, a correlation between a cell having an unknown location and multiple adjacent known cells can be used to determine a more accurate location of the radio-coverage cell having an unknown location.

For instance, referring to Figure 5, a cell (Cell Z) on a competitor network for which cell locations are not known has been determined as having three adjacent cells (Cell A, Cell B and Cell C) on an affiliate network for which cell locations are known. These adjacent cells could have been determined from calls made in respect of three different mobile nodes, for instance, two calls made by a first mobile node on cells Z and A respectively within the predetermined maximum time separation, two calls made by a second mobile node on cells Z and B respectively within the predetermined maximum time separation and two calls made by a third mobile node on cells Z and C respectively within the predetermined maximum time separation. In this case, referring to Figure 2, the data processor 10' is able to query the database 43 in the

HPLMN 40 to determine the geographical location of each of cells A, B and C. The location of the cell (Cell Z) having an unknown location can then be inferred as the mean average of the locations of Cell A, Cell B and Cell C, in accordance with the following equation:

$$\text{CellZ} (X, Y) = \text{Mean} (\text{CellA} (X, Y), \text{CellB} (X, Y), \text{CellC} (X, Y))$$

Where CellZ(X,Y) is the inferred geographical location of Cell Z, CellA(X,Y) is the known geographical location of Cell A, CellB(X,Y) is the known geographical location of Cell B and CellC(X,Y) is the known geographical location of Cell C.

In the example of Figure 5, the cell (Cell Z) having an unknown location is on a competitor network, whereas the known cells (Cells A, B and C) are on an affiliate network. This need not necessarily be the case, because once cells on a competitor network have been located by the data processor, their location becomes known and they could be used to locate further cells in accordance with the above technique.

Figure 6 is a schematic flow diagram summarising the above process. The process is illustrated in Figure 6 as comprising two stages: a data capture stage (all steps above the dashed line) and a data analysis stage (all steps below the dashed line). In the data capture stage, at a step S1, a call is made to or from a mobile node via a particular radio-coverage cell. As a result of the call, signalling messages are generated at a step S2 as part of the operation of the mobile radio network, these signalling messages including an indication of the Cell ID from which the communications session took place. The Cell ID of the cell of an unknown location is communicated to the home network of the mobile node in the form of SS7 signalling as described above with reference to Figure 1, and a TAP file used to communicate billing information to the home network is also generated as described above with reference to Figure 2. At a step S3, the SS7 signalling or TAP file is intercepted by a signal capture device and then the location of the radio-coverage cell to which the mobile node is affiliated (network identifier and Cell ID), the identity (e.g. IMSI) of the mobile node and the time of the call are all detected. Then, at a step S4, the network identifier, Cell ID, IMSI and time of call are stored into a call database. Steps S1 to S3 will then be repeated for each call made for a given period of time, for instance an hour, day, week or month. In this way, a database is populated with a list

of calls made on various radio coverage cells at different times and by different mobile nodes.

At a step S5, when the data capture stage has been completed, the data analysis stage commences. The data analysis stage can commence at any time after all data has been collected in the data capture stage. In particular, at the step S5, call data is read from the call database in respect of a particular mobile node, as identified by the IMSI stored in the call database. At a step S6, it is determined whether any two calls made by the mobile node were made using different radio-coverage cells, and if so whether the calls were made within a maximum call separation $T_{\max}$ of each other. Only if both of these criteria are met for two calls made by a mobile node can those calls be used as part of the cell locating process, in which case processing will move on to a step S8. If no two calls made by the mobile node satisfy the two criteria, then, at a step S7 it is determined that the calls made by that mobile node cannot be used for the purpose of locating radio-coverage cells, and processing returns to the step S5, where data is read in respect of another mobile node. On the other hand, if two calls are found at the step S6 which satisfy the criteria as to being on different cells and the criteria as to being made within the predetermined time $T_{\max}$ from each other, then at a step S8, reference is made to a location database to determine, at a step S9, whether one or both of the cell locations are known. If neither cell location is known, or if both cells locations are known, then the two calls cannot be used to locate radio-coverage cells and processing returns to the step S5. If the location of one of the cells upon which a call was made is known, but the location of the other cell is unknown, then at a step S10 the known location will be fetched from the location database, and at a step S11 the fetched location will be used to estimate the location of the cell having an unknown location. Following this, processing returns to the step S5, where further data can be read from the call database.

As set out above, this process can be repeated in respect of the same cell, with each repeat enabling the cell to be associated with another geographical location. The multiple geographical locations associated with a single cell of unknown location can then be averaged, thereby iteratively improving the accuracy of the estimated location of the unknown cell.

Cell Location Precision

The likely precision with which the above location determination model operates can be assessed by using the model to locate known cells. When the estimated location has been generated for the known cells, it is possible to compare the
5 estimated locations with the known locations of the cells to measure any differences between the estimated and known locations. These differences can be converted into statistical parameters which can be used to associate a degree of confidence with the estimated locations for cells having an unknown location within a given network environment.

10

Location Based Services

An alternative method of locating radio-coverage cells which have an unknown location is illustrated in Figure 7. In Figure 7, the operation of the BTS 532, the BSC 533, the MSC 534, the CDR 535, the DCH 536 and the VLR 537 of a VPLMN 530, the
15 HLR 541 of a HPLMN 540 and the Billing System 542 operate in the same way as the BTS 32, the BSC 33, the MSC 34, the CDR 35, the DCH 36 and the VLR 37 of the VPLMN 30, the HLR 41 of the VPLMN 40 and the Billing System 42 as described in relation to Figure 2. However, in this embodiment a geographical location associated with a mobile node 531 when affiliated to a particular radio-coverage cell is
20 determined by a positioning service, for instance the Global Positioning Service (GPS), provided in respect of the mobile node 531. The location data identifying the position of the mobile node 531 can be communicated to the data processor 550 by any available method, for instance by sending a signalling message across the VPLMN 530 and the HPLMN 540. In this case, there is no need to correlate a cell having an
25 unknown location with cells having a known location to infer a geographical location of the cell having an unknown location, because the geographical location of the cell having an unknown location is measured directly. This enables accurate locating of cells on a competitor network, by associated Cell IDs at measured locations. This technique can be used to confirm or assess the accuracy of the estimate of the location
30 provided by the adjacent cell method discussed above, or to obtain some initial cell-location readings which can then be used as cells having a known location in the adjacent cell method.

An example of a location-based application architecture for providing the above positioning information and Cell ID is illustrated in Figure 8. In Figure 8, a mobile node 611 is currently affiliated to a visited network 610. The mobile node 611 includes an embedded location based services application which enables the mobile node 611 to act as a location based services client. A location based services (LBS) server 613 is operable to issue the mobile node 611 with a location request instruction at a step S21, and the mobile node 611 is responsive to the location request instruction to provide the geographical location of the mobile node 611 to the LBS server 613 at a step S22. The geographical location (X, Y) is then communicated to a cell database 614 at a step S23.

At around the same time as steps S21, S22 and S23, the LBS server 613 issues a MAP (Mobile Application Part) ATI (Any Time Interrogation) message to the HLR 615 of the mobile node at a step S24. Then, at a step S25, the HLR 615 issues a MAP PSI (Provide Subscriber Information) message to the VLR 616 of the visited network. The MAP PSI message is a request for the VLR to provide certain subscriber information, including an indication of the radio-coverage cell to which the mobile node is currently affiliated. In response to the MAP PSI message, the VLR 616 issues to the HLR 615, at a step S26, a MAP PSI response message which includes an indication of the identity of the radio coverage cell, location area and VLR to which the mobile node 611 is currently affiliated. In response to the MAP PSI response message, the HLR 615 issues, at a step S27, a MAP ATI response message to the LBS server 613 including the indication of the identity of the radio-coverage cell, location area and VLR to which the mobile node 611 is currently affiliated. This cell identity data is then communicated to the database 614 at a step S28, where it is correlated with the location data, thereby forming an association in the database 614 between cell identity and geographical location.

While this technique could be used as an alternative to the adjacent cell method, the mobile node must include a location-based application, whereas the adjacent cell method can use all roaming traffic. The location-based method can be used where there is no known network to provide the known adjacent cells, in which case the location-based method can discover the location of a few cells, and then further cells can be located using the adjacent cell method.

Radio Coverage Mapping

A radio-coverage map can be generated from the detected and located radio-coverage cells within a given geographical area. In addition to a general measure of radio-coverage, it is also possible to build a coverage map according to technology, type of service, and also by associated quality of service. For example, the radio-coverage of an access network could be determined in respect of a particular radio access technology (e.g. 2G or 3G), or in respect of a particular packet technology (e.g. GPRS, EDGE, 3G, HSDPA or HSUPA).

10

Radio Access Technology

It is possible to gain a view on the deployment progress of 3G technology on a competitor network. This can be achieved by determining not only the location of cells within the competitor network, but also whether specific 3G services (e.g. video-telephony) have been provided to a mobile node with that cell. This information could be retrieved from CAMEL (Customised Applications for Mobile network Enhanced Logic) signalling back to the home network, or from the TAP file, which includes billing information relating to the 3G only services.

Packet Technology

Based on the packet CDR (TAP), it is possible to gain an idea of the bandwidth allocated per cell, by computing average and maximum throughput used by roamers on the visited network. This bandwidth information could provide a good indication of the packet technology deployed by competitor networks. The average and maximum throughput could be rated taking into consideration knowledge of the terminal equipment used, because the terminal identifier IMEI (International Mobile Equipment Identity) is also present in the TAP file. For instance, some terminal equipment may have limited bandwidth capabilities and may therefore contribute to the bandwidth information (for instance a GPRS-based terminal may not be able to deal with 3G type communications).

30

Market Share per Segment

Based on cellular information regarding different networks operating within the same country, it is possible to determine indicators such as the market share within a predetermined location or in respect of a particular transport route. For instance, the market share could be determined for a segment, which could be one of:

- Region
- Train
- Road
- Boat
- Airport

Region Segment

Radio coverage within a particular country or area can be described hierarchically in terms of cell, location area and VLR. An example of this hierarchy is schematically illustrated in Figure 9. Referring to Figure 9, each radio-coverage cell (e.g. CI 1.1.1, CI 1.1.2) is associated with a particular location area (e.g. LAC 1.1) described by a location area code (LAC). There may be many radio-coverage cells associated with a single location area. Each location area is associated with a particular VLR (in Figure 9 only a single VLR is illustrated, this being VLR 1). There may be many location areas associated with a single VLR. Accordingly, considering radio-coverage on a VLR level will provide a coarse picture of radio-coverage within a particular country, whereas considering radio-coverage on a cell level will provide a fine picture of radio-coverage and considering radio-coverage on a location area level will provide an intermediate degree of granularity. In terms of assessing market share, using the VLR level could be useful when considering large regions of a country, whereas the cell level and location area level could be useful when considering smaller regions of a country. The location area is likely to provide a degree of granularity which is well matched to the topology of a particular country.

This can be better understood from Figure 10, which is a table illustrating an example count of VLRs, LACs and Cell IDs for each network, as identified by a Mobile Network Code (MNC). It can be seen from Figure 10 that each network

includes more Cell Ids than LACs, and more LACs than VLRs. It will be appreciated then, that a Cell ID will relate to a smaller geographical area than a LAC or VLR.

The location of some or all of the radio-coverage cells within a network can be determined by one of the techniques described above. A geographical location for a particular location area can be taken to be the mean of the location of all known cells associated with that LAC, and the "location" of a VLR can be taken to be either the mean of the location of all known cells associated with that VLR or the mean of all location areas associated with the VLR. In this way, any cell, location area or VLR can be identified as belonging to a particular geographical region within a country. It is then possible to determine the respective market shares for multiple networks in particular regions of a country.

Train Segment

The start location and the end location of a train trip, and the approximate time taken for the train to move from the start location and the end location can be easily determined, for instance from train timetables. It is possible to identify one or more VLRs for each mobile operator which cover the start location, and one or more VLRs from each mobile operator which cover the end location. It is therefore possible to identify mobile nodes which have taken a particular train trip by specifying the following conditions:

- 1) That the mobile node enters one of a first list of VLRs (VLR IN) corresponding to the start location;
- 2) That the mobile node exits one of a second list of VLRs (VLR OUT) corresponding to the end location; and
- 3) That the time difference between VLR IN and VLR OUT falls within a range of prescribed values.

The home network of a mobile node will be aware of any change in the VLR to which the mobile node is affiliated. This is necessary because the home network needs to know which VLR the mobile node is affiliated to in order to route any incoming calls or messages to the correct VLR for relay to the mobile node. Accordingly, whenever the mobile node switches affiliation to a new VLR, an indication of the new VLR is communicated to the HLR in the home network as part of the location update

procedure. It will be appreciated that the times at which these changes in VLR occur can be tracked by the home network. In this way, the home network is able to collect the information required to identify mobile nodes which are affiliated first with one of the first list of VLRs (VLR IN) and then with one of the second list of VLRs (VLR OUT), and to identify whether the time difference between VLR IN and VLR OUT for these mobile nodes fall within the range of prescribed values. If so, it is assumed that the mobile node was one of the mobile nodes on the train because the time difference between VLR IN and VLR OUT matches an expected time difference for the train route.

At a simplistic level, the criteria could be based only on whether the time difference between VLR IN and VLR OUT is less than a first predetermined duration. This would exclude less expeditious modes of transport than the mode of transport for which the market share is being defined. However, the time difference between VLR IN and VLR OUT may also need to be greater than a second predetermined duration, thereby excluding more expeditious modes of transport as well.

For example, referring to Figure 11, VLR IN includes VLRs of three different operators, in particular VLR_IN Op1, VLR_IN Op2 and VLR_IN Op3. VLR OUT also includes VLRs of three different operators VLR_OUT Op1, VLR_OUT Op2 and VLR_OUT Op3. The scheduled duration of the relevant journey might be 45 minutes, and a range of prescribed values of 40 to 50 minutes might therefore be specified as a requirement for a transition from VLR IN to VLR OUT to be considered to belong to the train segment. In this way, it is possible to work out a market share with respect to all operators.

An example of a train route which can be assessed in this way is schematically illustrated in Figure 12, which shows a train route between Brussels, in Belgium, and Paris, in France. The train route intercepts the France-Belgian border, at a geographical location covered by a list of VLRs VLR IN, the VLRs being provided by operators of French mobile networks. A train station in Paris is the destination of the train route, and a list of VLRs VLR OUT cover the geographical area of the train station in Paris. All mobile nodes which enter the French mobile networks at a VLR of VLR IN and subsequently become attached with a VLR of VLR OUT at around a time Δt are deemed to form part of the Brussels to France train segment.

Figure 13 is a schematic flow diagram illustrating the process of detecting mobile nodes which form part of the train segment for a particular train line. The process is separated into two stages, these being a data retrieval stage, and a data analysis stage. In the data retrieval stage, at a step S41, a mobile node moves, and as a result of this movement the radio conditions experienced by the mobile node may change, resulting in a decision by the mobile node or the network for the mobile node to change affiliation to a different radio-coverage cell. The change of affiliation results in SS7 signalling being generated at a step S42, and in the present case, where the new radio-coverage cell is associated with a different VLR from the existing radio-coverage cell, a location update to be performed at a step S44 in which signalling messages are communicated to the home network to which the mobile node is subscribed to update the home location register of the mobile node with the current VLR of the mobile node.

The signalling messages communicated to the HLR are detected by a signal capture device such as the signal capture device 14 illustrated in Figure 1. At a step S45 it is determined whether an area update message involves a change of affiliation to a VLR which is identified as a VLR IN. If the area update message indicates that a mobile node has changed affiliation to a VLR which is identified as a VLR IN, then at a step S47 the mobile IMSI (International Mobile Subscriber Identity) and a time of the area update are stored to a VLR_IN database. If the area update message does not indicate that the mobile node has changed affiliation to a VLR which is identified as a VLR IN, then at a step S46 it is determined whether the area update message involves a change of affiliation to a VLR which is identified as a VLR OUT. If the area update message indicates that a mobile node has changed affiliation to a VLR which is identified as a VLR OUT, then at a step S48 the mobile IMSI and a time of the area update are stored to a VLR_OUT database. When the VLR_IN database and the VLR_OUT database have been compiled, then the data retrieval stage is complete, and the data analysis stage can commence. In the data analysis stage, at a step S49, the VLR IN database and the VLR OUT database are correlated with respect to IMSI, thereby identifying all mobile nodes which have become affiliated to both VLR_IN and VLR_OUT. At a step S50, mobile nodes for which the time they became affiliated to VLR OUT t_{out} subtracted by the time they became affiliated to VLR IN t_{in}

is equal to the transit time T_{trans} of the train journey plus or minus a time slot margin T_{slot} are detected and are determined as constituting part of the train segment.

Figure 14 schematically illustrates, in respect of the train route illustrated in Figure 12, a correspondence between the time which mobile nodes performed a location update in respect of a VLR on the list VLR IN and the time when a train was scheduled to cross the French-Belgian border. The dark vertical lines underneath the x-axis of the graph of Figure 15 represent the time when trains crossed the France-Belgian border, and the vertical lines above the x-axis represent the number of mobile nodes which performed a location update in respect of a VLR on the list VLR IN as a function of time. It can be seen that there is a good correlation between the location update signalling and the train times.

Figure 15 schematically illustrates, again in respect of the train route illustrated in Figure 12, the distribution of time (in the range from 30 minutes and 52 minutes) for mobile nodes which became attached first to VLR IN, and then to VLR OUT. The mean value is between 35 and 45 minutes, which is in line with the time of a train journey from the France-Belgian border to Paris (below 50 minutes). The time variance will depend mainly on two factors, the first being the speed of the train, and the second being the fact that VLR IN and VLR OUT will not have the same topology for different operators. In particular, the VLRs of different operators within the VLR IN and VLR OUT list will not be perfectly coincident in terms of geographical area, and this will effect the time of a location update on the train route.

Once the train segment has been identified, it is possible to identify the market share for the train segment for each of operators 1 to 3. For instance, example market share values are illustrated in Figure 16, in which a national share, a train share and a train share / national share ratio are provided for each of operators 1 to 3. The national share is the share of the market across the whole country. The train share is the share of the market for a particular train route (for instance the train route from Brussels to Paris of Figure 12) and the train share / national share ratio indicates whether the train share for a particular operator is above the national average for that operator. In the case of Figure 16, it can be seen that operator 1 has a relatively small share of both the overall and train markets, but in relative terms is very strong in the train market

compared with the national market as a whole. Both operators 2 and 3 have a train market share which is fairly close to the national market share of the operator.

Various market share indicators can be computed, including the market share based on mobility, using the MAP SS7 signalling, and the market share based on call control for various services such as mobile originating calls (MOC), mobile terminating calls (MTC), short messaging service (SMS), both mobile originating and terminating, and GPRS communications, in each case using SS7 signalling or TAP files.

The principles which apply to the train segment described above also apply to the road segment, where a car journey by motorway can be treated in the same way as a train journey with fixed start and end points and a prescribed minimum and maximum duration. Additionally, the same principles also apply to the boat segment, where VLR IN may correspond to one port and VLR OUT may correspond to another port, and where the approximate journey time between the two ports is known. VLR IN and VLR OUT may be in either the same or different countries.

Loss Cell Detection

For linear segments such as the train or road segment, it is possible to detect the cells where traffic is lost from one operator to another operator. This is schematically illustrated in Figure 17. In particular, based on the MAP SS7 signalling, it is possible to trace mobility events, such as MAP Location Update and to identify the VLRs covering the segment. When the relocation of a mobile node from a first operator (VLR Op1) to a second operator (VLR Op2) is detected, the point at which this occurs represents the "loss cell". Due to the linear nature of the train or road segment, it is possible to convert the time of the loss (Δt) into a position on the train line or the road, thereby providing a good estimate of the loss cell location. Equally, a gain cell can be detected where a mobile node relocates from the second operator (VLR Op2) to the first operator (VLR Op1), and the time of the gain (Δt_2) can be converted into a position on the train line or the road.

Airport Segment

Figure 18 schematically illustrates a way of defining a market share for an airport. In particular, an airport segment could be defined as all mobile nodes which have become affiliated with a VLR corresponding to the airport location, but which
5 had no previous mobility detected by the home network with the neighbouring VLRs. This is consistent with the situation which occurs with passengers entering the airport from a plane, where the mobile node would have been switched off while transiting through the neighbouring VLRs. However, this measure would also cover users who move into the area of the VLR corresponding to the airport region from a distant VLR
10 with their mobile phone switched off by a mode of transport other than an aircraft, and then switch their mobiles on again. In order to overcome this limitation, it may be necessary to take into consideration the previous VLR used by each mobile terminal, and the time delay between the time of location update to the previous VLR and the time of location update to the airport VLR.

15 In this way, it is also possible to distinguish between domestic flights (which will have the previous VLR in the same country as the airport VLR) and international flights (in which the previous VLR will be in a different country to the airport VLR).

Additional Features

20 The cell identities and locations from competing networks could also be used to perform network activities such as traffic steering or network routing. For instance, traffic steering could be performed based on the cell ID of the visited networks, thereby improving border control. Routing decisions, controlled for example by CAMEL, could be carried out based on VLR position, the VLR position being
25 determined by calculating the mean of the locations of radio-coverage cells corresponding to the VLR.

Based on the cellular information (Cell ID and LAC) for all operators in one country, it will be possible for an operator to deliver Location Based Services such as weather, traffic, and assistance to their subscribers which are roaming into unknown
30 networks.

Various modifications of the embodiments herein before described may be made without departing from the scope of the present invention. For example, while

embodiments of the invention have been described in relation to a GSM network, it will be appreciated that the invention may be equally applicable to other types of mobile telecommunications network. Also, while embodiments of the present invention attribute mobile nodes to a particular transport route in dependence on
5 visitor location registers (VLR) with which the mobile node is, or has been, associated, the invention may also be provided in dependence on other network entities with which the mobile terminal is, or has been, associated. While the transport route has been described as one of a road, rail, sea or air route, other modes of transport can also be envisaged, such as tram or pedestrian walkway, to which embodiments of the
10 present invention may be applicable. The signalling data used in the identification of the location of radio-coverage cells and in the identification of a particular transport route may be collected continuously from a mobile telecommunications network, or may be periodically provided by the mobile telecommunications network.

CLAIMS

1. A telecommunications system operable to provide a facility for mobile nodes to communicate via one or more mobile radio networks, comprising
a data processor operable
5 to detect a communication from a mobile node via a first radio-coverage cell at a first time,
to detect a communication from the mobile node via a second radio-coverage cell at a second time,
to determine that the difference between the second time and the first time is
10 less than a predetermined value, and
to identify the location of the first radio-coverage cell based on knowledge of the location of the second radio-coverage cell.
2. A telecommunications system according to claim 1, comprising
15 a location database for storing the geographical location of the second radio-coverage cell, and wherein
the data processor is operable to identify the location of the first radio-coverage cell based on the geographical location of the second radio-coverage cell stored in the location database.
20
3. A telecommunications system according to claim 1 or claim 2, wherein the data processor is operable
to detect a first plurality of communications from one or more mobile nodes via the first radio coverage cell at a respective plurality of first times,
25 to detect a second plurality of communications from said one or more mobile nodes via radio-coverage cells which are different to the first radio-coverage cell at a respective plurality of second times,
to determine that the difference between respective ones of the plurality of first times and the plurality of second times is less than the predetermined value, and

to identify the location of the first radio-coverage cell based on knowledge of the location of the radio-coverage cells which are different to the first radio-coverage cell.

5 4. A telecommunications system according to any preceding claim, wherein the data processor is operable to detect the communications from the mobile node from a transaction application part file generated by the mobile radio network to which the mobile node was affiliated, the transaction application part file including an indication of the radio-coverage cell via which the communication occurred.

10

 5. A telecommunications system according to any of claims 1 to 3, wherein the data processor is operable to detect the communications from the mobile node from signalling messages produced by the mobile radio network to which the mobile node was affiliated as a result of the communication from the mobile node, the
15 signalling messages including an indication of the radio-coverage cell via which the communication occurred.

 6. A telecommunications system according to any preceding claim, wherein the one or more radio networks are visited networks to which mobile nodes
20 subscribed to a home network can become affiliated, and via which the mobile nodes may communicate.

 7. A data processor for identifying the location of radio-coverage cells within one or more mobile radio networks, the data processor being operable
25 to detect a communication from a mobile node via a first radio-coverage cell at a first time,
 to detect a communication from the mobile node via a second radio-coverage cell at a second time,
 to determine that the difference between the second time and the first time is
30 less than a predetermined value, and
 to identify the location of the first radio-coverage cell based on knowledge of the location of the second radio-coverage cell.

8. A method of identifying the location of radio-coverage cells within one or more mobile radio networks, comprising
detecting a communication from a mobile node via a first radio-coverage cell at
5 a first time,
detecting a communication from the mobile node via a second radio-coverage cell at a second time,
determining that the difference between the second time and the first time is less than a predetermined value, and
10 identifying the location of the first radio-coverage cell based on knowledge of the location of the second radio-coverage cell.
9. A computer program providing computer executable instructions which when loaded onto a computer causes the computer to perform the method according to
15 Claim 8.
10. A data carrier having a recording medium, the recording medium having recorded thereon a computer program according to Claim 9.
- 20 11. A signal representing the computer program according to Claim 10.
12. A telecommunications system operable to provide a facility for mobile nodes to communicate via one or more mobile radio networks, the mobile nodes being subscribed to a home network and visiting a visited network, the telecommunications
25 system comprising a data processing apparatus operable
to detect a first area update message which is generated when a mobile node subscribed to the home network becomes affiliated to a radio-coverage cell associated with one of a first predetermined list of visitor location registers and which is communicated to the home location register of the home network of the mobile node,
30 the first predetermined list of visitor location registers being associated with a first location,

to detect a second area update message which is generated when the mobile node becomes affiliated to a radio-coverage cell associated with one of a second predetermined list of visitor location registers and which is communicated to the home location register of the home network, the second predetermined list of visitor location registers being associated with a second location,

to determine a time difference between the generation of the first area update message and the generation of the second area update message, and

to identify whether the mobile node is associated with a particular transport route in accordance with the determined time difference.

10

13. A telecommunications system according to claim 12, wherein the mobile node is associated with the transport route if the time difference is less than a first predetermined time difference.

15

14. A data processing apparatus according to claim 13, wherein the mobile node is associated with the transport route if the time difference is greater than a second predetermined time difference, the second predetermined time difference being greater than the first predetermined time difference.

20

15. A data processing apparatus for identifying mobile nodes which transit between an origin area and a destination area, the mobile nodes being subscribed to a home network and visiting a visited network, the data processing apparatus being operable

to detect a first area update message which is generated when a mobile node subscribed to the home network becomes affiliated to a radio-coverage cell associated with one of a first predetermined list of visitor location registers and which is communicated to the home location register of the home network of the mobile node, the first predetermined list of visitor location registers being associated with a first location,

30

to detect a second area update message which is generated when the mobile node becomes affiliated to a radio-coverage cell associated with one of a second predetermined list of visitor location registers and which is communicated to the home

location register of the home network, the second predetermined list of visitor location registers being associated with a second location,

to determine a time difference between the generation of the first area update message and the generation of the second area update message, and

5 to identify whether the mobile node is associated with a particular route or region in accordance with the determined time difference.

16. A method for identifying mobile nodes which transit between an origin area and a destination area, the mobile nodes being subscribed to a home network and
10 visiting a visited network, comprising

detecting a first area update message which is generated when a mobile node subscribed to the home network becomes affiliated to a radio-coverage cell associated with one of a first predetermined list of visitor location registers and which is communicated to the home location register of the home network of the mobile node,
15 the first predetermined list of visitor location registers being associated with a first location,

detecting a second area update message which is generated when the mobile node becomes affiliated to a radio-coverage cell associated with one of a second predetermined list of visitor location registers and which is communicated to the home
20 location register of the home network, the second predetermined list of visitor location registers being associated with a second location,

determining a time difference between the generation of the first area update message and the generation of the second area update message, and

25 identifying whether the mobile node is associated with a particular route or region in accordance with the determined time difference.

17. A computer program providing computer executable instructions which when loaded onto a computer causes the computer to perform the method according to Claim 16.

30

18. A data carrier having a recording medium, the recording medium having recorded thereon a computer program according to Claim 17.

19. A signal representing the computer program according to Claim 18.

20. An apparatus for identifying mobile nodes which transit between an
5 origin area and a destination area, the mobile nodes being subscribed to a home
network and visiting a visited network, the apparatus comprising

means for detecting a first area update message which is generated when a
mobile node subscribed to the home network becomes affiliated to a radio-coverage
cell associated with one of a first predetermined list of visitor location registers and
10 which is communicated to the home location register of the home network of the
mobile node, the first predetermined list of visitor location registers being associated
with a first location,

means for detecting a second area update message which is generated when the
mobile node becomes affiliated to a radio-coverage cell associated with one of a
15 second predetermined list of visitor location registers and which is communicated to
the home location register of the home network, the second predetermined list of
visitor location registers being associated with a second location,

means for determining a time difference between the generation of the first
area update message and the generation of the second area update message, and

20 means for identifying whether the mobile node is associated with a particular
route or region in accordance with the determined time difference.

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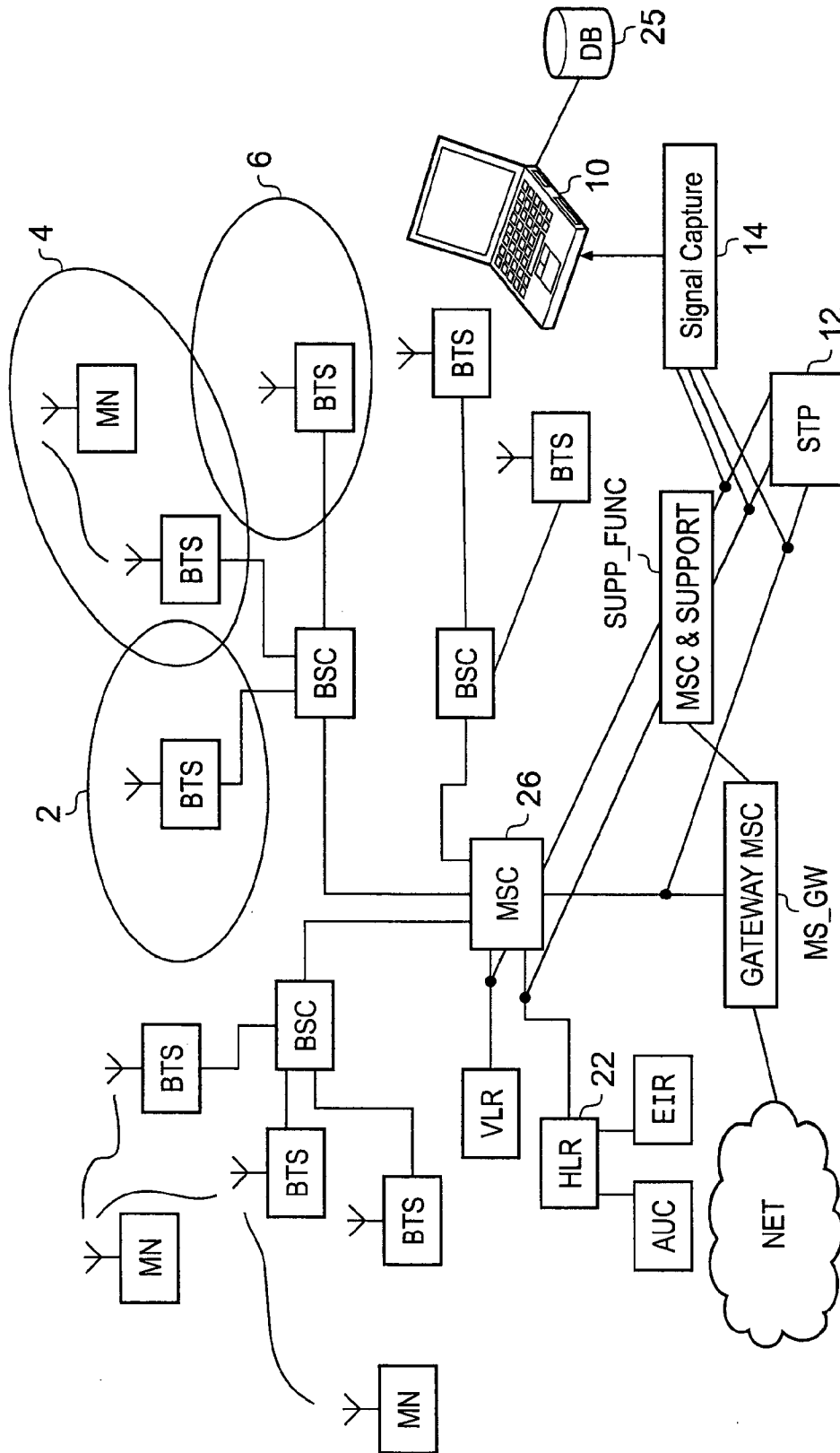


FIG. 1

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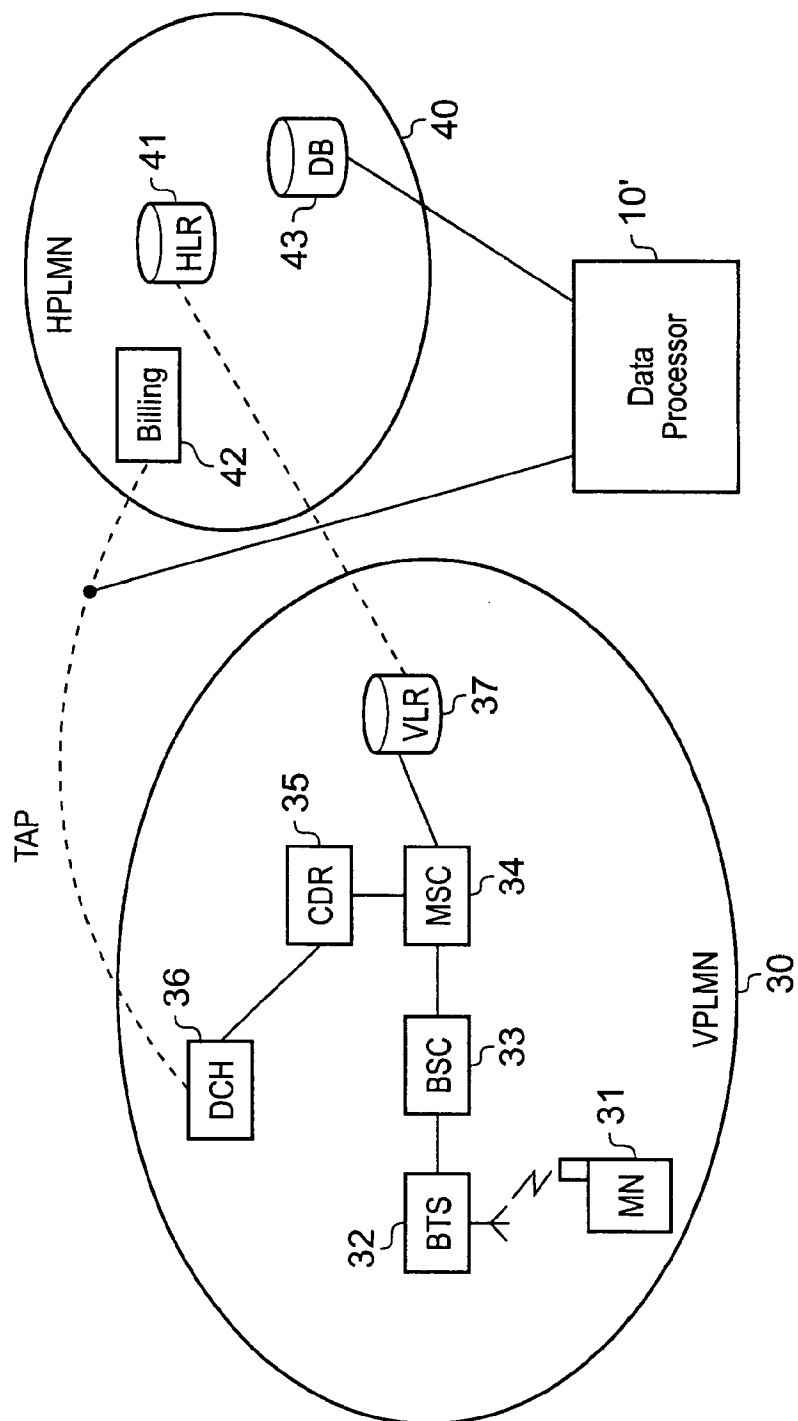


FIG. 2

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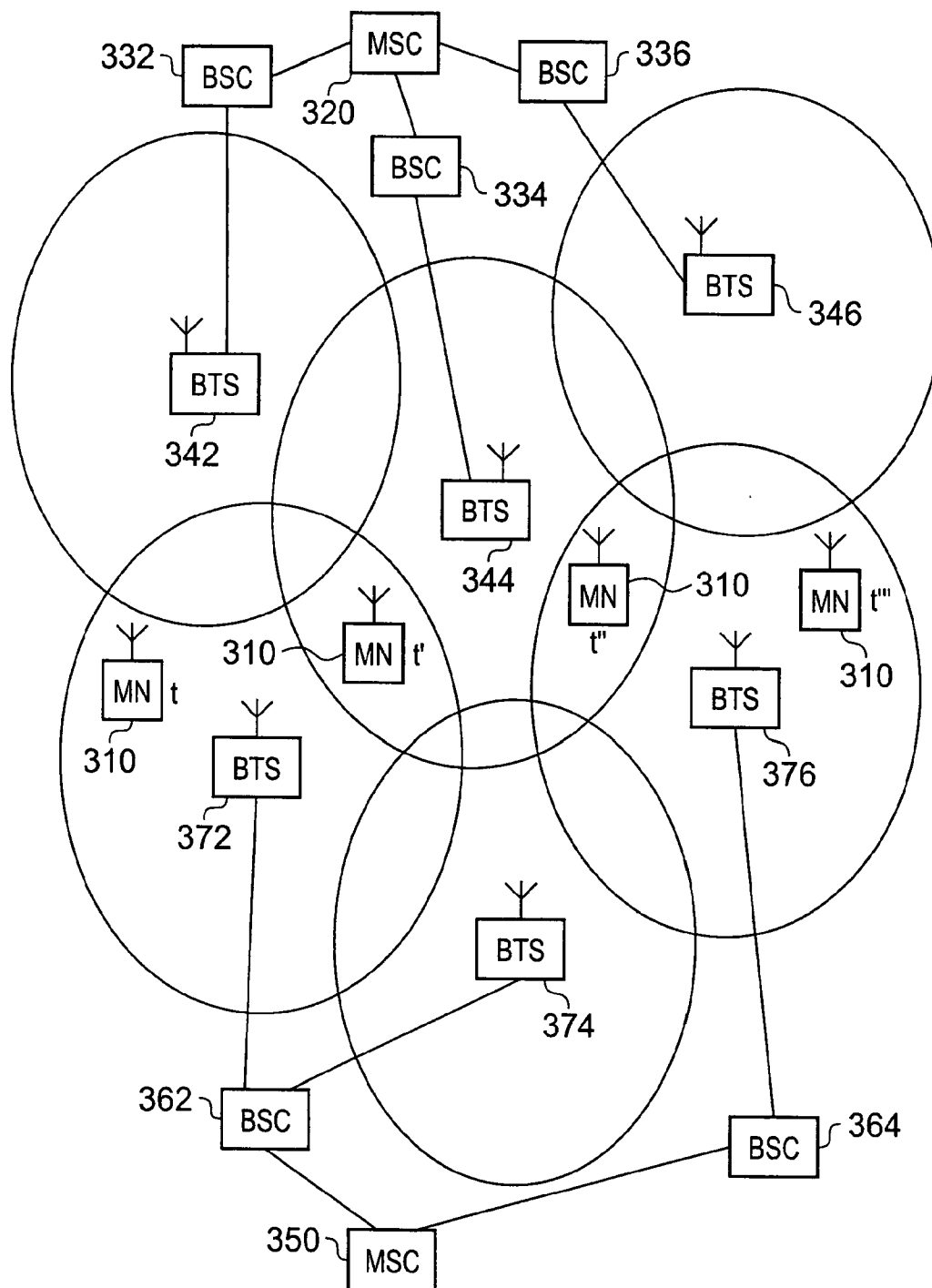


FIG. 3

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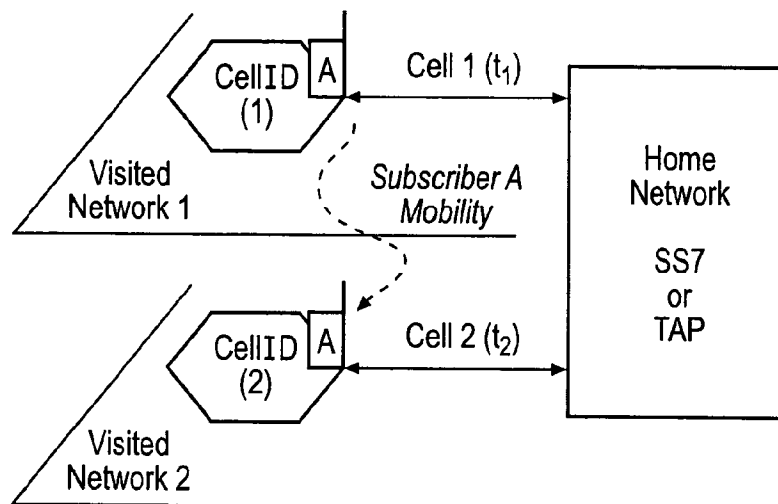


FIG. 4

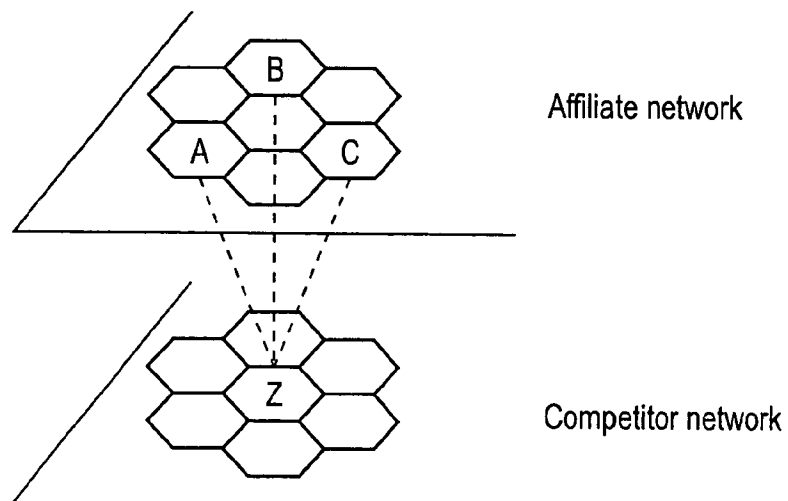


FIG. 5

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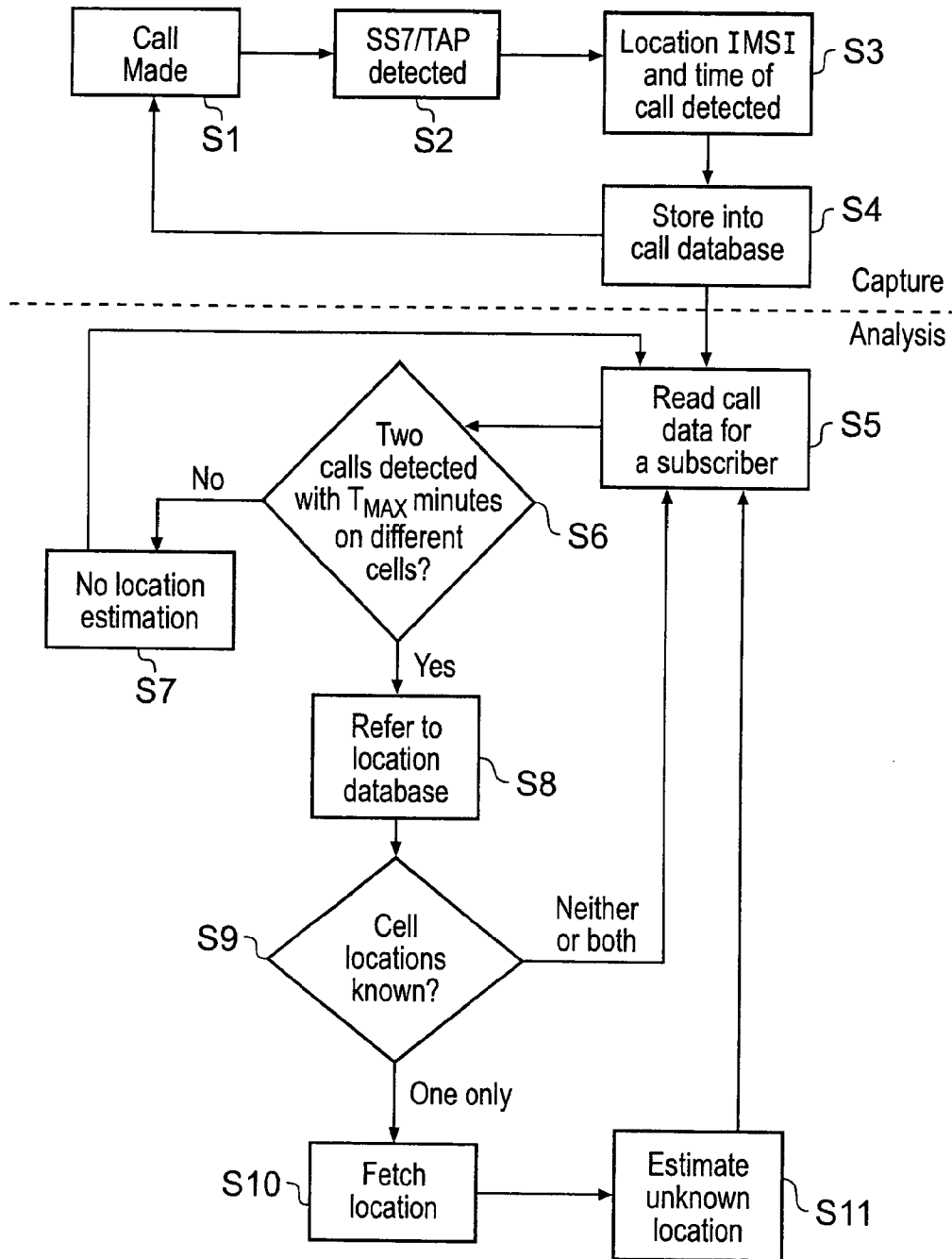


FIG. 6

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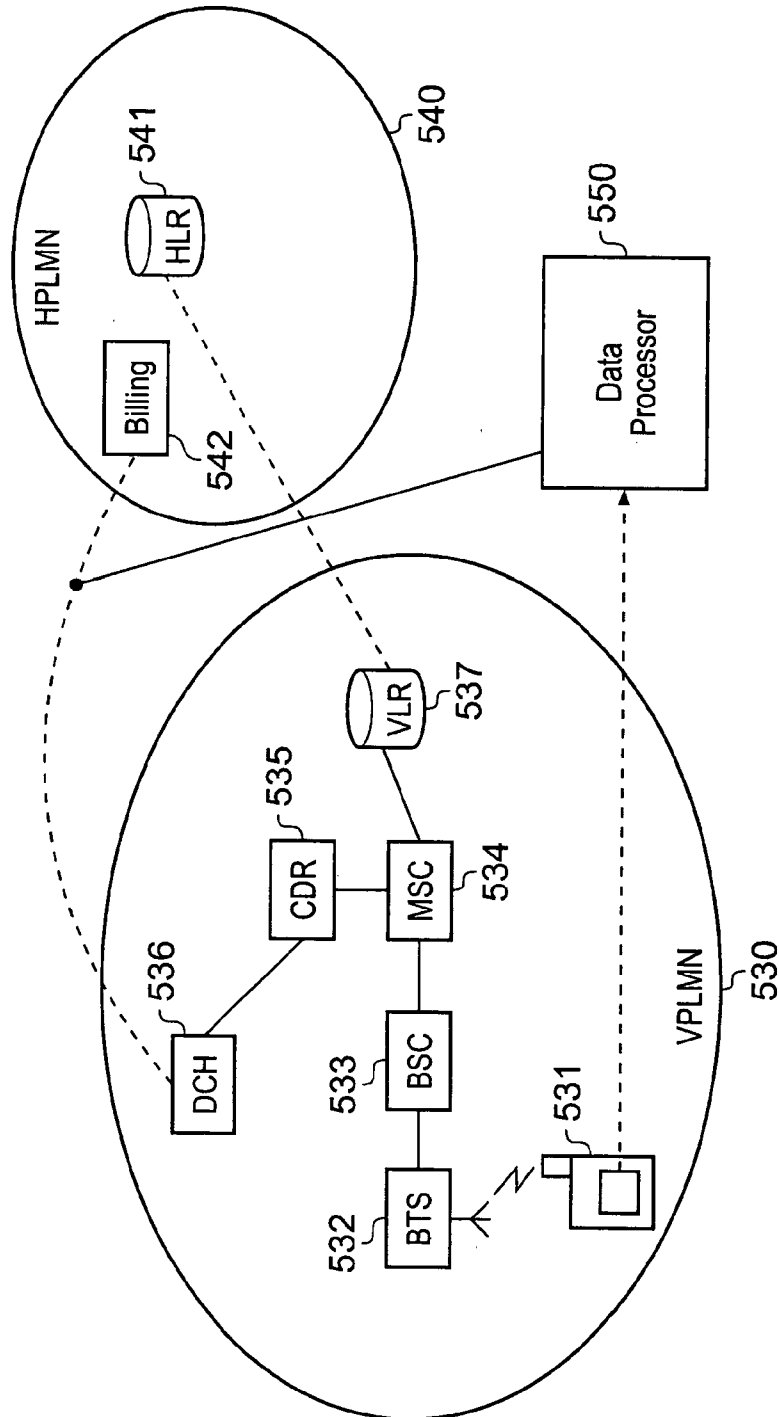


FIG. 7

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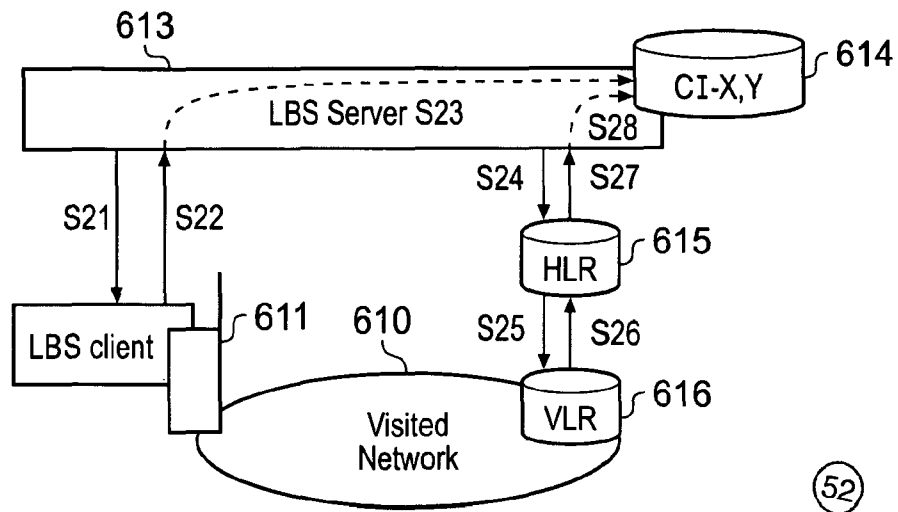


FIG. 8

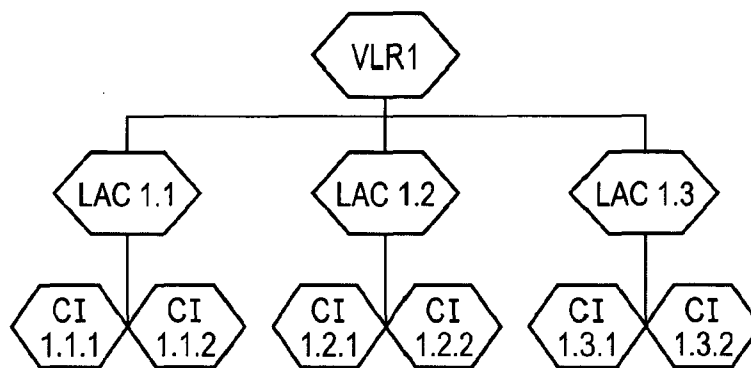


FIG. 9

Count of VLRs, LACs and Cell IDs by network (MNC)			
MNC	Count of VLRs	Count of LACs	Count of Cell IDs
01	56	270	42007
02	12	12	89
10	92	165	8587
13	45	123	19283
20	1	9	76
88	6	18	53

FIG. 10

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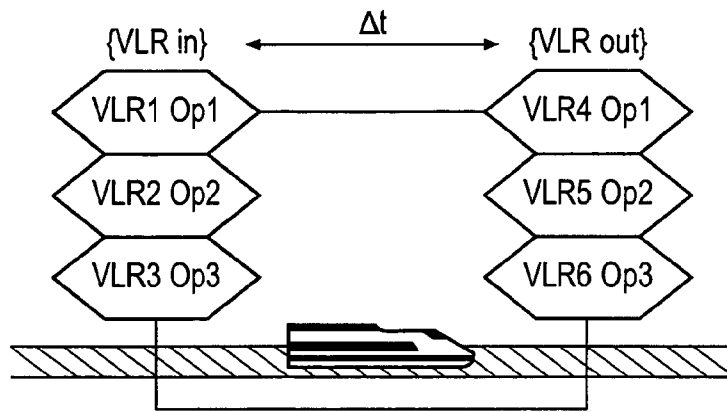


FIG. 11

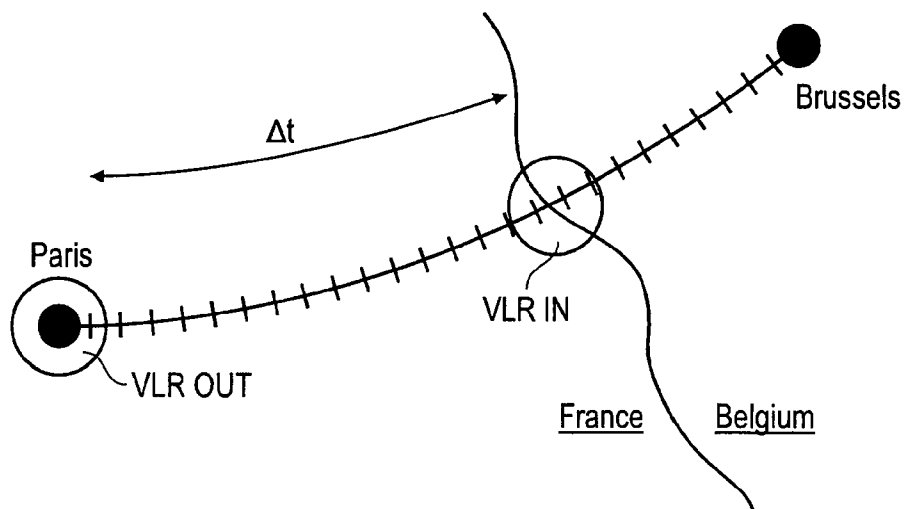


FIG. 12

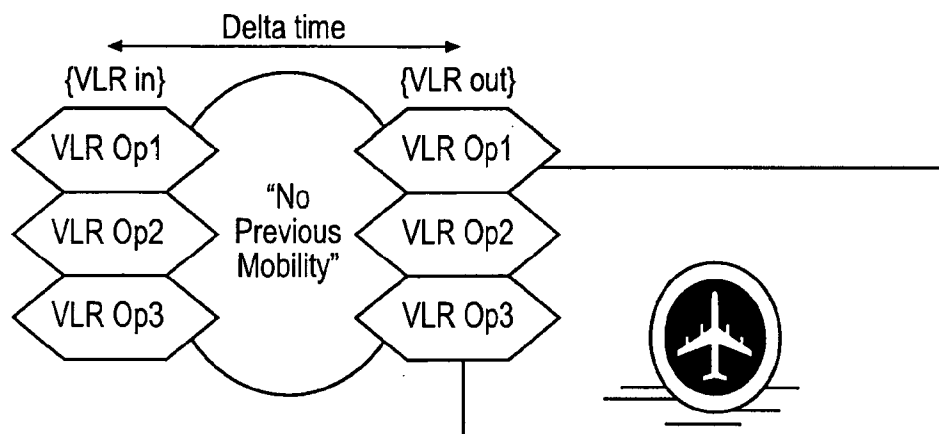


FIG. 18

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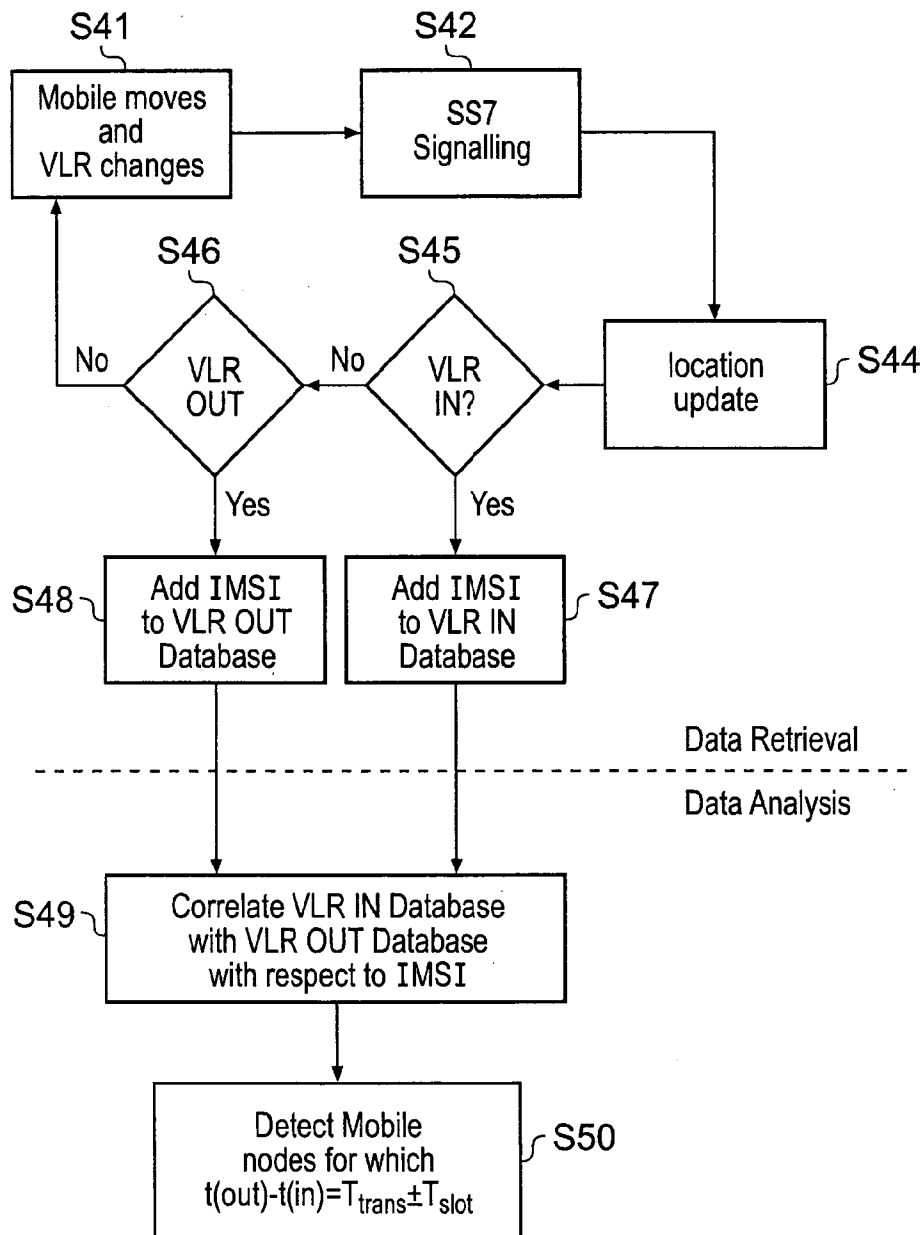


FIG. 13

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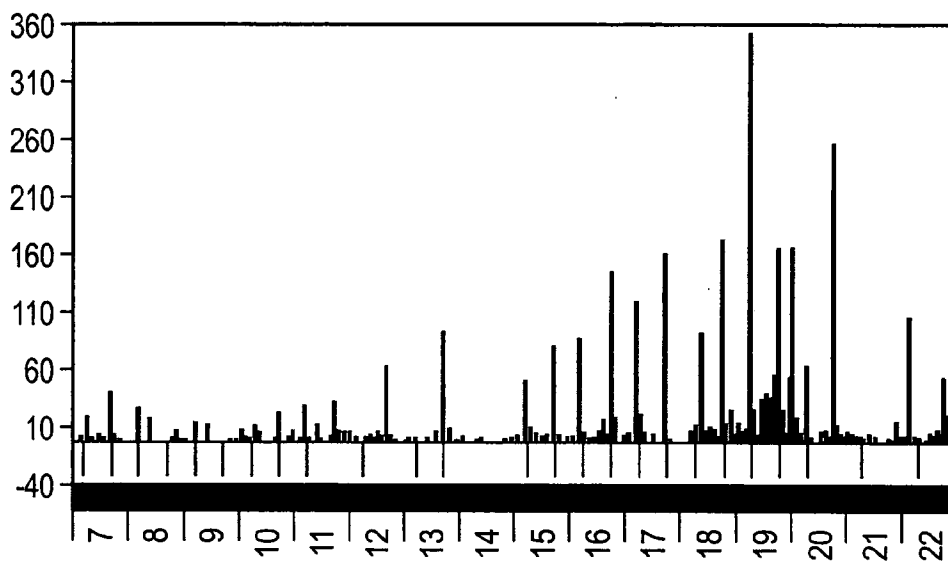


FIG. 14

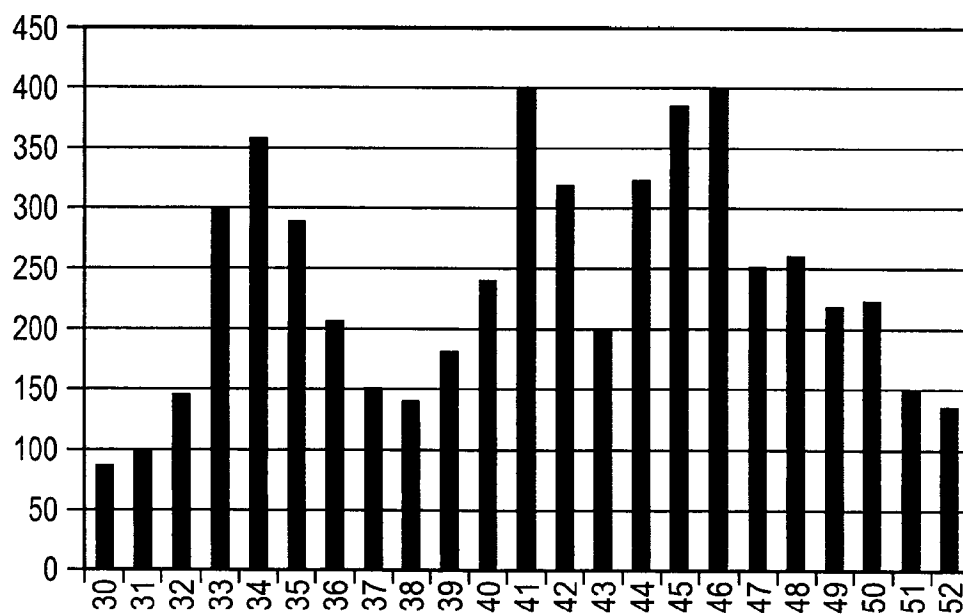


FIG. 15

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Market Share Analysis			
Network	National Share	Train Share	Train/National
Operator 1	3.50%	7.00%	199.85
Operator 2	12.05%	12.76%	105.91
Operator 3	84.45%	80.25%	95.02

FIG. 16

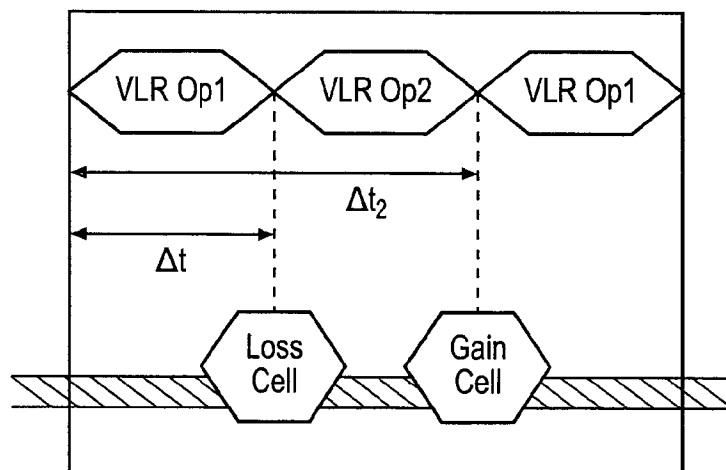


FIG. 17

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2007/007047

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04Q7/36 H04Q7/38 G01S5/00

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)

H04Q G01S

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 practical, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 415 576 A (MOTOROLA INC [US]) 28 December 2005 (2005-12-28) page 4, line 20 - page 5, line 10 page 7, line 23 - page 9, line 7 page 10, line 26 - page 12, line 9	1-20
A	WO 02/071781 A (CELLULAR DESIGN SERVICES LTD [GB]; BELLOUL BACHIR DR [GB]) 12 September 2002 (2002-09-12) page 6, line 19 - page 15, line 6	1-20
A	US 2002/082017 A1 (HATTORI KIYOSHI [JP]) 27 June 2002 (2002-06-27) paragraph [0015] - paragraph [0017] paragraph [0049] - paragraph [0070] paragraph [0089] - paragraph [0094]	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

12 November 2007

Date of mailing of the international search report

19/11/2007

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2007/007047

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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