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(54) Title: METHOD AND SYSTEM TO DETERMINE THE POSITION OF A CELLULAR DEVICE WORLD-WIDE

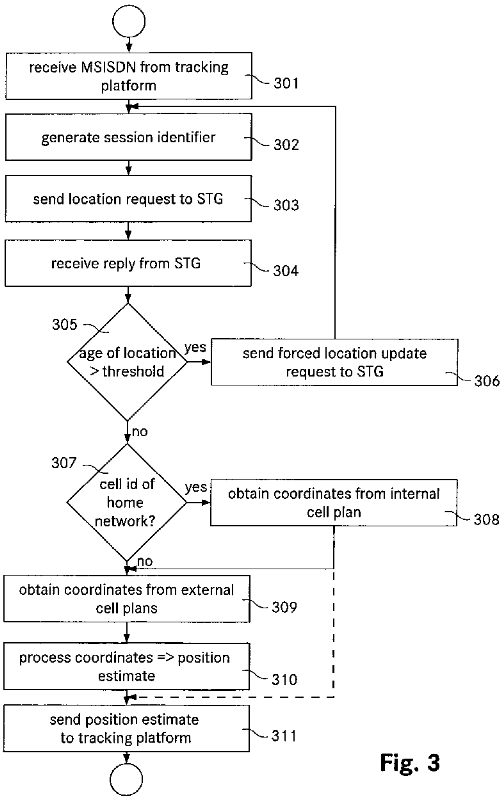

Fig. 3

(57) Abstract: In a method to determine the position of a cellular device the position is determined by a server (100) distant from the cellular device, the server (100) in particular being connected to a network management (150) of a service provider of the cellular device. The method comprises the steps of providing the server (100) with cell identification information identifying the current cell where the cellular device is actually logged in or was last seen; and at least for a current cell not belonging to a network of the service provider and not belonging to a network of selected roaming partners of the service provider, the server (100) using a software interface for connecting to a service provider independent external cell plan database (130.1, 130.2) for obtaining coordinates based on the cell identification information. This avoids the need of exchanging cell plans or concluding specific contracts between network operators in order to localise a cellular device worldwide. If the position is needed not at the cellular device, traffic is reduced and the cellular device may be simple, cost and energy efficient.

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METHOD AND SYSTEM TO DETERMINE THE POSITION OF A CELLULAR DEVICE WORLD-WIDE

Technical Field

The invention relates to a method to determine the position of a cellular device and to a method of tracking an object. The invention further relates to a system to determine the position of a cellular device.

Background Art

Various methods exist for determining the geographical position of a cellular device such as a mobile telephone connected to a cellular network. Some of the methods are based on dedicated components of the cellular device such as receivers for a global positioning system, e. g. GPS. Others are based on transceivers of the cellular network (such as the base stations of the cellular network) or on transceivers of other networks such as wireless local area networks (WLAN).

In cellular networks the area supplied by the network is divided into a plurality of radio cells, whereas each radio cell covers a more or less defined and delimited geographical region. Among the information that can be obtained in a cellular network is typically an identification of the cell where the device is actually logged in or was last seen. In a GSM/UMTS network it is the CGI (Cell Global Identity) which uniquely identifies the country, network and cell identification number of this cell. The CGI can be mapped to the rough geographical location of the cellular device if the list of all cells and according positions is known. This list is called "cell plan" and typically a network operator's business secret.

An important factor of success of today's cellular network is the fact that most of the networks allow for contacting subscribers of other cellular networks, essentially on a world-wide basis, i. e. the networks are capable of "roaming". This means that a cellular customer may automatically make and receive voice calls, send and receive data, or access other services, including home data services, when travelling outside the geographical coverage area of the home network, by means of using a visited network.

The determination of location may be device-based, i. e. the cellular device determines its position. This is especially favourable if the position is needed on the cellular device, e. g. by location based applications running on the cellular device.

Due to the fact that the service provider's cell plans are not easily available, several non-telecom operator companies have reverse-engineered their own cell plan databases independent of the service providers' cell plans, usually by employing cellular devices (e. g.

"smartphones") of friendly users having an integrated network-independent location system (such as a GPS component), sending their actual position determined using the location system together with the current CGI back to the company. This principle is aimed at device-based localisation of cell phones without a GPS chip, i. e. the database built up using the location system equipped cellular devices is queried by other cellular devices (especially devices without GPS or devices which do not have GPS coverage) in order to determine their current location. The major drawback of such databases is that they are often incomplete, inconsistent, outdated or contain false data, at least in certain regions. The database contains only a "snapshot" of the cell plan at a given moment. It is almost impossible to log all cells worldwide, and the data is prone to be outdated since network operators can renumber or update their cells at any time.

Alternatively, the determination of location is network-based, i. e. the needed basic information for determining the location of the cellular device is read out of the cellular network. This is especially favourable in cases where the location is not needed on the cellular device but by a third party, e. g. on a server distant from the cellular device, as network-based localisation avoids the need for specific software and/or dedicated hardware components on the cellular device as well as for additional traffic to and from the cellular device.

In cases where the determination is based on the current cell of the device usually a cell plan of the network service provider is used to convert the basic information to location information such as geographical coordinates. As most of the network service providers (telecom operators) are not sharing their cell plan, a major drawback of cellular network-based location as described before is that it works inside the service provider's own network, but usually not if the cellular device uses a visited network, unless there is an explicit agreement between the service provider of the user's home network and the service provider of the visited network which includes the exchange or access to the networks' cell plans.

As an example, EP 0 714 589 B1 (Verizon) discloses a method for determining the location of a mobile station in a cellular system where a "mobile station locator" (MSL) interacts with and is the recipient of location-determinative cellular data from the cellular network and which uses radio coverage maps for translating the cellular data into geographical information. In particular, a code representing the identity of a mobile station (such as MIN or ESN) is transmitted from a mobile switching center to the mobile station locator, whereafter the MSL queries the mobile switching center with the code, requesting network data on the respective mobile station. The network identification data are transmitted contemporaneously with a voice channel from the mobile switching center serving the current cell site of the mobile station.

However, this solution requires the radio coverage maps of the service provider(s) which are generally not accessible for networks operated by other service providers as mentioned above.

EP 0 603 390 B1 (Rimer et al.) relates to the determination of locations of mobile vehicles as well as corresponding messaging systems. The required information is gathered by tapping roaming network information of a cellular network, thereby avoiding the need to place costly telephone calls or to alter existing base station or switch hardware or software. The disclosed system comprises an interface computer that is connected to a roaming network joining a number of individual cellular systems, the roaming network data is scanned for predetermined cellular subscriber station identification numbers that correspond to stations of interest. The information obtained by the interface computer is forwarded to a location computer, where the position of the vehicles is computed. The location is computed by looking up in a table the geographical information assigned to a certain switch number, whereas the contents of this table are derived by gathering coverage information from the FCC or cellular operators or by empirical tests. The position accuracy may be improved if in addition to the switch number also the cell site number is obtained, for that purpose, the host switches of the original network are modified to communicate also the cell number to the home system.

This method requires a database that includes not only the cell plan of a single network service provider but also of further operators. The buildup of this data base is cumbersome and often requires specific collaboration of the other operators. However, as the prior art method relates to the localization of vehicles which usually operate within a defined geographical region, covered by a certain number of cellular networks, these restrictions are acceptable in the context of the prior art system shown in EP 0 603 390 B1.

Summary of the invention

It is the object of the invention to create a method and a system to determine the position of a cellular device pertaining to the technical field initially mentioned, that allows for reliably determining the position of cellular devices essentially independent of the whereabouts of the devices, i. e. substantially world-wide.

The solution of the invention is specified by the features of claim 1. According to the invention the position is determined by a server distant from the cellular device, whereas the method comprises the steps of

a) providing the server with cell identification information identifying the current cell where the cellular device is actually logged in or was last seen;

b) at least for a current cell not belonging to a network of a service provider of the cellular device and not belonging to a network of selected roaming partners of the service provider, the server using a software interface for connecting to a service provider independent external cell plan database for obtaining coordinates based on the cell identification information.

This means that the method includes the use of cell plan databases that are independent of the service provider as well as of the roaming partners of the service provider. Today, such cell plan databases are available e. g. from Google, Navizon, fire eagle or OpenCellID. These databases comprise cell plans of a plurality of providers, which have been usually obtained by reverse-engineering, i.e. by using cellular devices including means to determine their location independent from the cellular network, as described above.

In the context of the inventive method, the external cell plan databases may be used if it is detected that the current cell of the cellular device does not belong to the network of the service provider. However, it is not required that these external databases are used for all cells not belonging to the service provider as there may be specific roaming agreements between the service provider and further operators (selected roaming partners of the service provider) that include the access to the cell plan database of the further operators such that no external database is needed in that case. On the other hand, even for cells belonging to the service provider the external database may be used, either in order to obtain additional information to improve the precision of the determined location or if the determination is always exclusively based on external databases, independent of whether an "official" cell plan is available or not. If the external cell plan database is accurate this may even lead to positions that are more meaningful than the precise coordinates of the base stations as they do not represent the position of the base station but a certain average of the actual positions of the users contacting the base station. Finally, the external databases may constitute a fall-back option in the case any of the usually available cell plan databases of the network service providers are not available when required.

The software interface may be a web service provided by the provider of the external cell plan database or any other kind of application programming interface (API) or database access.

Accordingly, a system according to the invention to determine the position of a cellular device, comprises

a) a server distant from the cellular device,

b) an interface for connecting the server to a service provider independent external cell plan database,

whereas

c) the server receives cell identification information identifying the current cell where the cellular device is actually logged in or was last seen; and

d) at least for a current cell not belonging to a network of a service provider of the cellular device and not belonging to a network of selected roaming partners of the service provider, the server contacts the external cell plan database for obtaining coordinates based on the cell identification information.

One of the advantages of the solution according to the invention is that it does not require the exchange of cell plans or contracts between network operators in order to localise a cellular device worldwide.

One radio cell covers regions of up to 30km in radius, whereas in practice the regions are usually considerably smaller. If needed, the location precision may be enhanced using a series of technologies based on CGI that are known as such, e. g. Cell Global Identity with Timing Advance (CGI+TA), Enhanced CGI (E-CGI), Cell ID for WCDMA, Uplink Time Difference Of Arrival (U-TDOA) and/or Any Time Interrogation (ATI). These techniques may optionally be employed in the context of the inventive method and system.

Preferably, the cell identification information comprises a cell global identity (CGI). The CGI is a set of data that provides a unique identification of every cell of any cellular network world-wide, working according to the GSM/UMTS standard. It consists of the Mobile Country Code (MCC), the Mobile Network Code (MNC), the Location Area Code (LAC) and the Cell Identifier (CI). The MCC consists of 3 digits and identifies the country, the MNC is 2 digits and identifies the network within the country, the LAC has a maximum length of 16 bits and identifies a location area within the network. Finally, the CI again has a maximum length of 16 bits and identifies the cell within the location area.

Due to the fact that all GSM/UMTS networks use the CGI for keeping track of the location of mobile subscribers, that the CGI is usually available from roaming partners without special agreements and that most of the available service provider independent cell plan databases (such as Google, Navizon etc.) offer the retrieval of geographical coordinates based on the CGI this approach provides the best coverage.

Preferably, the server is connected to a network management of the service provider, and the server is provided with the cell identification information by the network management. Therefore, if the position is needed not at the cellular device but at the server or a third party having access to the server or being provided with information by the server, no user data traffic will be generated between the cellular device and the network and no additional software will be needed on the cellular device. Accordingly, the cellular device may be a simple, cost and energy efficient device.

Alternatively, the cell identification information is forwarded to the server by the cellular device, in particular using usual communication channels available on the cellular network (such as SMS or other services). This avoids the need of connecting the server to the network management, in particular in cases where the server is operated by a unit independent from the service provider.

Preferably, the method includes the step of the server making a request to the network management by providing a piece of information that uniquely identifies the cellular device, in particular the MSISDN in a GSM or UMTS mobile network. This allows for easily identifying the cellular device the location of which is required. The MSISDN consists of the Country Code (CC), the National Destination Code (NDC) and the Subscriber Number (SN). It uniquely describes every subscriber of any GSM/UMTS network world-wide. It provides sufficient information for identification of any of these subscribers.

Instead of the MSISDN the request may be based on other information identifying the cellular device such as the International Mobile Subscriber Identity (IMSI) which consists of the Mobile Country Code (MCC, 3 digits, see above), the Mobile Network Code (MNC, 2 digits, see above) and a Mobile Subscriber Identification Number (MSIN, max. 10 digits). It is stored in the Subscriber Identity Module (SIM) of the cellular device.

The aforementioned preferred embodiments relate to GSM/UMTS networks. It has to be kept in mind however, that other types of cellular networks (such as CDMA) feature comparable functionalities and that the scope of the invention extends not only to GSM/UMTS but to cellular networks in general.

The system for carrying out the inventive method preferably comprises a signalling transfer gateway for connecting the server to the network management, the signalling transfer gateway being programmed to:

a) translate requests of the server into a protocol supported by the network management;

b) forwarding the translated requests to the network management;

c) receiving responses of the network management; and

d) forwarding at least some of the responses to the server.

Usually, the network management supports a number of standardized protocols that allow for the request of information (e. g. the SS7 protocol). The signalling transfer gateway supports one of these protocols as well as a protocol supported by the server. Furthermore, it features a hard- and/or software interface for connecting to the server (e. g. a usual LAN interface) as well as a hard- and/or software interface for connecting to the network management (e. g. an SS7 interface card). The signalling transfer gateway may be part of the server or of the network management, or it may be an independent component switched between the server and the network management. In some cases, the signalling transfer gateway may be realized completely by software.

In a GSM or UMTS mobile network the cell identification information is preferably requested from a Home Location Register (HLR) of the network management. The HLR is a database (which may be distributed) that stores inter alia the identifications (MSISDN and IMSI) of every cellular device registered to the network and images every number to the current Visitor Location Register (VLR). The VLR inter alia maps every identification to the address of the Mobile Switching Center (MSC) that is currently serving the cellular device. The HLR responds to the request by sending the available information, typically the CGI and the age of the information or an error message back to the signalling transfer gateway. The HLR may be queried based on the Signalling System 7 (SS7) protocol.

In networks of other types, different kinds of requests may be placed in order to obtain the required cell identification information.

In a certain embodiment of the invention, the server is automatically notified by the Home Location Register (HLR) about a cell change of the cellular device, i. e. there is push notification ensuring that the server always disposes of the actual cell identification information.

In further embodiments the server queries the HLR, e. g. by sending requests in regular intervals in order to update its list of cell identification information relating to the monitored cellular devices.

Preferably, for a single determination of a position a plurality of sets of coordinates from a plurality of cell plan databases is obtained and the plurality of sets of coordinates is statistically processed in order to obtain improved coordinates with higher accuracy. In a given case, the plurality of cell plan databases may include cell plans of the service providers and/or of selected roaming partners or they are exclusively telecom operator independent cell plans. In the following, the term "set of coordinates" describes a number of coordinate values required to identify a location, such as latitude and longitude.

By combining a plurality of cell plans, the availability, quality and hit probability for localisation is increased, while at the same time dependencies towards one cell plan are minimised. In principle, the statistical processing allows for obtaining coordinates that are more precise than just the coordinates of the base station of the cell, i. e. that allow for a higher accuracy.

In the context of a method where a plurality of cell plan databases is used, the statistical processing preferably involves the step of disregarding one of the plurality of sets of coordinates if a Mobile Country Code (MCC) of the cell global identity does not correspond to a country determined from said set of coordinates. This allows for excluding manifestly incorrect information in one of the databases.

In case at least three sets of coordinates are obtained, the statistical processing may involve the step of disregarding one of the plurality of sets of coordinates if it corresponds to a position that is significantly offset of positions of at least two other of the plurality of sets of coordinates. As an example, in any case only the sets of coordinates of two estimates are used that lie closest together; alternatively, the sets of coordinates of all estimates are used having a distance of the geometric centroid of all the sets of coordinates which is less than a certain measure, which may be a fixed threshold or proportional e. g. to the standard deviation (or median) of the distances of the coordinates from the geometric centroid.

Preferably, the statistical processing involves a weighting of at least some of the plurality of sets of coordinates, whereas the weighting is based on quality data relating to the cell plan databases (i. e. a kind of ranking of the quality of the databases). The weighting may be globally constant, i.e. a first cell plan database which is considered to be reliable has always a weighting of 0.6, a second one has a weighting of 0.3 whereas a third one has a weighting of 0.1. In preferred embodiments, the weighting may depend on the quality of the cell plan databases in a certain region or country. Finally, the weights may be dynamically updated using a self-learning process. This process may include the logging of inaccurate reported positions over time and reducing the weight of a certain source if it provides a large number of disregarded information.

In an embodiment of the invention, a plurality of successively obtained cell identification information is used by the server for determining the position of the cellular device. This allows for obtaining a more accurate position of the cellular device. As an example, in a case where it is detected that the cell identification changes back and forth between a first and a second cell, a position approximately between the first and the second base station may be assumed.

When a cellular device is in idle mode, there is no constant radio contact between base station and the cellular device. Moving from one cell to the other both served from the same Base Station Controller (BSC) in idle mode is not detected by the network. This may lead to outdated location information when retrieving the CGI. There are periodical location update requests from the network management, but only in the range of hours (usually 1h to 4h, depending on network configuration). Therefore, the method preferably includes the step of forcing a location update of the cellular device. The forced location update allows for always having the latest location information available. There exist several mechanisms for forcing a location update, such as

a. sending a Type-0 SMS (blind SMS, hidden SMS), such an SMS is empty and not shown at the cellular device;

b. initiating a Network initiated USSD (NI USSD), this is supported by most cellular devices and allows for the network pushing information to the cellular device, inter alia sending a NI USSD leads to a location update;

c. initiating a call; or

d. forcing a network ping

In order to avoid unnecessary traffic, it is particularly preferred that a maximum age of the available cell identification information may be specified, and that a forced location update request is only initiated if the returned information is older than the maximum age. It is to be noted that forced location updates are not supported by all possible roaming partners and therefore, the possibility of requesting a forced location update may be limited to certain networks.

The inventive method is particularly well suited to be used when tracking an object using an object tracking system comprising a control system and a tracking module including a cellular device and being linked to the object to be tracked. In this case, the method as described before is used to determine the position of the cellular device, whereas the server is part of the control system of the object tracking system.

In such a tracking method the position of the cellular device is needed by the control system. Having a network-based method reduces the traffic between the control system and the tracking module. Furthermore, it reduces the steps that have to be carried out by the tracking module, thereby reducing battery consumption. Finally, the tracking module may be a very simple device without the need for a localisation system (such as a GPS component) or the capability of accessing web services. The inventive method allows for substantially world-wide tracking of the object, even under conditions where GPS coverage is not available (i. e. indoors)

Other fields of use of the inventive method comprise e. g. the localisation of cellular devices (and their users) in case of emergencies.

Especially in the case of tracking, the obtained coordinates and/or the determined position (from a plurality of coordinates) may be compared with expected positions of the tracked object. As an example, if the method is used for tracking goods sent by postal or courier services, determined positions may be compared with known locations corresponding to traffic ways, airports, distribution centers etc. This allows for obtaining more precise positions and may be used in the context of statistical processing of a plurality of coordinates.

Other advantageous embodiments and combinations of features come out from the detailed description below and the totality of the claims.

Brief description of the drawings

The drawings used to explain the embodiments show:

Fig. 1	a schematical illustration of the structure of a GSM or UMTS cellular network;
Fig. 2	a schematical representation of the architecture of an embodiment of a system according to the invention;
Fig. 3	a flowchart of a method to determine the position of a cellular device according to an embodiment of the invention; and
Fig. 4A-D	schematical illustrations for the explanation of the statistical processing of a plurality of coordinates obtained from a plurality of cell plan databases

In the figures, the same components are given the same reference symbols.

Preferred embodiments

Figure 1 is a schematical illustration of the structure of a (prior art) GSM or UMTS cellular network. The network comprises a number of cells 1.1, 1.2, 1.3 with corresponding base transceiver stations (BTS) 2.1, 2.2, 2.3. Every BTS 2.1...2.3 is connected to a base station controller (BSC) 3.1, 3.2, whereas several BTS may be connected to the same BSC. All BSC 3.1, 3.2 are connected to a mobile switching center (MSC) 4 which has access inter alia to a home location register (HLR) 5 and a visitor location register (VLR) 6.

To every MSC 4 a mobile country code (MCC) and a mobile network code (MNC) are assigned. Every BSC is assigned a location area code (LAC), and every BTS is assigned a Cell Identifier (CI). Therefore, every cell may be uniquely defined by stating

MCC+MNC+LAC+CI, this set of data being denoted as cell global identity (CGI). The subset MCC+MNC+LAC is denoted as local area ID (LAI).

The home location register 5 relates the unique International Mobile Subscriber Identity (IMSI) of a cellular device connected to the network to the MSISDN of the device and the Mobile Station Roaming Number (MSRN) which contains the current visitor country code (VCC), the visitor national destination code (VNDC) and the identification of the current MSC together with the subscriber number.

The visitor location register 6 relates the Local Mobile Station Identity (LMSI), a temporary identification that is assigned to a mobile station that visits another network than its home network with the MSRN, the IMSI, the MSISDN and the Temporary Mobile Subscriber Identity (TMSI) and the LAI.

The Cell Identifier (CI) of a given cellular device is known at the mobile switching center (MSC) 4. It may be obtained together with the LAI by sending a corresponding request to the home location register (HLR) 5 such as an ATI (Any Time Interrogation) request. The HLR will forward to the request to the VLR and from there the request is forwarded further to the MSC. The MSC will send the response back passing the same stations, i. e. via VLR and HLR to the requesting server.

Figure 2 is a schematical representation of the architecture of an embodiment of a system according to the invention. The system includes a server, namely location interpreter 100, which is connected to a signalling transfer gateway 110 and to an internal cell plan database 120 of the service provider. The location interpreter 100 further has access to a number of external cell plan databases 130.1, 130.2 over the internet 140. The signalling transfer gateway 110 accesses a GSM network 150 of the service provider. The GSM network 150 is connected to further GSM networks 160.1, 160.2, 160.3 of roaming partners of the service provider.

The information produced by the location interpreter 100 may be accessed e. g. by a tracking platform 200 which may itself be connected to the GSM network 150 in order to exchange information over the network, e. g. for controlling the tracking devices. The components not belonging to the inventive system, namely the GSM networks 150, 160.1...160.3 and the tracking platform 200 are shown with dashed lines.

The signalling transfer gateway 110 is used as a gateway to the SS7 protocol supported by the network management of the GSM network 150. Signalling System Number 7 (SS7) is a set of telephony signalling protocols which are used to set up most of the world's public switched telephone network calls. The main purpose is to set up and tear down calls. Other uses include number translation, prepaid billing mechanisms, short message service (SMS), and a variety of other mass market services. In addition to the SS7 interface the signalling transfer gateway 110 features a TCP interface by which it is connected to the location interpreter 100. The signalling transfer gateway 110 offers interfaces to issue ATI (Any Time Interrogation) requests and receive ATI responses over SS7. In particular, the signalling transfer gateway 110 may issue a request to obtain the Cell Global Identity (CGI) of a cellular device having a certain MSISDN. After receipt, the signalling transfer gateway 110 will forward the CGI to the location interpreter 100. Accordingly, the signalling transfer gateway 110 essentially translates requests received from the location interpreter 100 by means of the TCP interface to SS7 requests and translates back the result of the request in order to be sent over TCP to the location interpreter 100.

The internal cell plan database 120 as well as the external cell plan databases 130.1, 130.2 provide conversion from the CGI into a location estimation in the form of geographical coordinates (such as latitude and longitude). In addition the databases may provide an indication of accuracy.

The location interpreter 100 controls the process of determining the position of the cellular device. Based on an MSISDN of a cellular device (which has been obtained e. g. from the tracking platform 200) it instructs the signalling transfer gateway 110 to issue a SS7 request to the network management of the GSM network 150 in order to obtain the CGI of the cell where the cellular device is actually logged in or was last seen. After receipt of the CGI this data is forwarded to one or several of the cell plan databases, 120, 130.1, 130.2 in order to obtain coordinates. If only one set of coordinates (such as latitude and longitude) is received this set of coordinates may be forwarded to the tracking platform 200 (or another service or user needing the information) or stored for retrieval by the platform, service or user. If a plurality of coordinates is received this plurality is statistically processed as described in more detail below.

Suitable signalling transfer gateways 110 are available on the market. They are responsible for transferring signalling messages from one protocol/transport to another procotol/transport, such as between SS7 and IP. The CGI may be obtained from the network management by the signalling transfer gateway 110 sending a corresponding command such as ATI (Any Time Interrogation) request over the SS7/MAP (Mobile Application Part) protocol. The request will be processed by the network management and a response is provided back to the signalling transfer gateway.This will return the CGI and the status of the query and optionally further information such as the time elapsed since the last determination of the CGI (Age of Location). If the returned information is older than a predefined maximum age, a forced location update request is initiated by either sending an NI-USSD request, a Type-0 (empty) SMS or by any other means to force a location update.

As an example, an ATI Lookup consisting of two messages 3920 and 4920 may be employed. The entire communication consists of a single request and a single reply. The request consists of the following fields:

parameter name	**Description**
MSISDN	the MSIDSN of the cellular device the cell identification information is requested of (mandatory)
HLR_ID	the MSISDN of the HLR hosting the MSISDN (optional)
COUNTER	a unique session identifier assigned by the requesting application (mandatory)
REQ_STATUS	ask for the subscriber's state? (0: no, 1: yes) (optional)
REQ_LOCATION	ask for location information and cell id? (0: no, 1: current location, 2: location) (optional)
REQ_IMEI	ask for the IMEI of the cellular device? (0: no, 1: yes) (optional)

The reply of the network management received by the signalling transfer gateway 110 is structured as follows:

parameter name	**Description**
STATUS	the status of the operation (0: success, others: error messages) (mandatory)
AGE_OF_LOCATION	number of minutes since the last position update (optional)
LOCATION	location type, longitude, latitude, uncertainty code (optional - only if supported by HLR)
LOCATION_NUMBER	the location number as defined in CCITT Rec Q. 763, Section 3.30 (optional)
VLR_ID	the id of the hosting VLR
LAI	the Location Area Identification (LAI) as defined in TS GSM 03.03 (number of 10 characters) (optional)
CELL_ID	the Cell Global Identification (CGI) as defined in TS GSM 03.03 (number of 14 characters) (optional)
SUBSCRIBER_STATE	state of the subscriber (optional)
COUNTER	the session identifier (mandatory)
IMEI	if requested: the IMEI of the cellular device

ATI requires CAMEL phase 1 and MAPv3. Both are widely supported by most GSM/UMTS networks and part of roaming agreements between providers,. such that the LAI and CELL_ID will be obtained even if the cellular device is currently connected to a network system of a roaming partner - in contrast to LOCATION which will only be available for selected networks. They allow for determination of the position of the cellular device using internal and/or external cell plan databases. In cases where more precise location information is received, e. g. where such information is obtained using timing advance or other techniques, this information may be used for the subsequent determination of the position of the cellular device, either alone or in combination with further information.

Fig. 3 is a flowchart of a method to determine the position of a cellular device according to an embodiment of the invention. It describes the steps that are carried out by the location interpreter 100, which is controlling the process. The described process starts with the location interpreter 100 receiving a MSISDN (i. e. an identification of a cellular device) from the tracking platform 200 (or any other service requiring an estimate of the position of the cellular device that has access to the location interpreter 100) (step 301). The request and the MSISDN are sent to the location interpreter 100 e. g. over a usual TCP/IP connection. At the end of the described process the location interpreter 100 sends the position estimate to the tracking platform 200 (or another requester, respectively) (step 311).

In between receiving the request and sending the reply, the method to determine the position of the cellular device is carried out, controlled by the location interpreter 100. First of all, the location interpreter 100 will generate a unique session identifier (step 302). This session identifier, together with the MSISDN received from the tracking platform 200 are parameters that are sent to the signalling transfer gateway (STG) 110 together with a request for obtaining the cell identification information relating to the cell where the cellular device is actually logged in or was last seen (step 303). As described above, the STG will itself send an ATI request to the network management of the cellular network of the service provider and receive a reply including inter alia the needed cell identification information such as the Cell Global Identity (CGI). This reply or only the needed data (session identifier, cell id information, age of location) is forwarded to the location interpreter 100 (step 304).

At the location interpreter 100 the age of location data received from the STG is compared to a certain predefined threshold (step 305). If it is found that the location data is older than the threshold a forced location update request is sent to the STG (step 306), as described above. After having sent a forced location update request, another session identifier is generated (step 302) and a new location request is sent to the STG (step 303) and a reply is received (step 304).

Next, it is checked whether the received cell identification is one belonging to the home network, i. e. to the network of the service provider of the cellular device to the network management of which the STG is connected to (step 307). If this is the case, a set of coordinates will be obtained from the internal cell plan of the service provider by consulting a corresponding database (step 308). If the cell identification does not belong to the home network (or a roaming network offering access to its cell plan to the service provider) the method directly continues with obtaining coordinates from external cell plans (step 309). In an alternative method, this step may be omitted if a set of coordinates has been obtained from the internal cell plan. In a further alternative method, the set of coordinates is always only obtained from external cell plans, i. e. steps 307 and 308 are omitted.

Next, the sets of coordinates obtained from internal and/or external cell plans are processed as described below (step 310). Note, that no processing might be necessary, if there is only exactly one set of coordinates. This will yield a position estimate which may be sent back to the tracking platform 200 (step 311).

The Figures 4A-4D are schematical illustrations for the explanation of the statistical processing of a plurality of coordinates obtained from a plurality of cell plan databases. For the sake of simplicity, the cells have an idealized hexagonal form. The squares indicate the position of the base stations (which do not have to be in the center of the cells, primarily due to topographical reasons). The circles indicate the location estimates obtained from the cell plan databases 1 - 4, whereas cell plan database 1 provides the internal cell plan of the service provider (if available) and databases 2 - 3 are external cell plan databases from independent providers.

Fig. 4A shows a situation where coordinates from the service providers cell plan, corresponding to the coordinates of the base station having the queried CGI, are available. Furthermore, sets of coordinates obtained from three external cell plans (databases) 2 - 4 have been received, whereas these coordinates are the "reverse-engineered" coordinates related to the cell of the queried CGI. It is to be noted that the set of coordinates obtained from database 4 corresponds to a location which is in another country, whereas the MCC of the CGI does not match with that other country.

In principle, the inventive method and system allow for different principles of statistically processing the coordinates, such as:

1. As coordinates from the (internal) cell plan of the service provider are available, the coordinates of other cell plan databases are disregarded (or not even retrieved). This means that the determined position corresponds to the set of coordinates obtained from the internal cell plan database 1 which correspond to the location of the cell's base station.

2. Sets of coordinates from external cell plans are taken into account. However, the coordinates from cell plan database 4 relating to a foreign location with unmatched MCC is completely disregarded. This means that a statistical average of the three other coordinates is calculated, for example the geometric centroid of the coordinates taken into account. In this case, the determined position will lie in between the coordinates obtained from databases 1, 2 and 3.

3. In addition, the different databases may be taken into account with different weights. As an example, data base 1 which provides the internal cell plan may have a weight of 0,5 whereas the other databases equally share the other 0,5 (i. e. in the displayed case data bases 2 and 3 both have weight 0,25). This will lead to a determined position which is closer to the location of the base station than the one obtained according to variant 2.

Fig. 4B again shows a situation where coordinates from the service providers cell plan, corresponding to the coordinates of the base station having the queried CGI, are available. Furthermore, sets of coordinates obtained from three external cell plans (databases) 2 - 4 have been received, whereas these coordinates are the "reverse-engineered" coordinates related to the cell of the queried CGI. It is to be noted that locations corresponding to the sets of coordinates obtained from databases 1, 2 and 4 are rather close together, whereas the set of coordinates obtained from database 3 corresponds to a location which is substantially farther away from a centroid of the coordinates obtained from the other three databases. Again, the inventive method and system allow for different principles of statistically processing the coordinates, such as:

1. Again, as coordinates from the (internal) cell plan of the service provider are available, the coordinates of other cell plan databases are disregarded (or not even retrieved). This means that the determined position corresponds to the set of coordinates obtained from the internal cell plan database 1 which correspond to the location of the cell's base station.

2. Coordinates from external cell plans are taken into account. However, the set of coordinates from cell plan database 3 relating to a location which is far away from the locations corresponding to the other coordinates is disregarded. As an example, locations might be disregarded the distance of which from the centroid of all the other coordinates is larger than twice the standard deviation of the average distance of the locations from the respective centroid of the other coordinates. In the case shown in Figure 3B, the Cartesian coordinates (in auxiliary units) are as follows:

data base	coordinates		centroid of other coord		distance
	X	Y	X	Y	
1	6.68	19.70	7.11	19.05	0.78
2	6.00	19.29	7.34	19.19	1.34
3	9.53	17.69	6.16	19.72	3.94
4	5.80	20.18	7.40	18.89	2.06

The standard deviation of the distance is 1.38. This means that the coordinates obtained from databases 1, 2 and 4 are taken into account, but not the coordinates of database 4, where the distance from the other coordinates centroid exceeds twice the standard deviation of the distance. The corresponding estimate of location is indicated by X.

3. As an alternative, all coordinates with the assigned weights (which are already a measure of the quality) are taken into account. The corresponding estimate of location is indicated by Y.

Fig. 4C shows a situation where no coordinates from the service providers' cell plan are available, but only coordinates from two external cell plans (databases) 2 and 4. There is no basis for excluding any of the two sets of coordinates and the estimate of location is obtained by calculating a weighted average of the coordinates of the two sets (weighted centroid). The displayed estimate Z has been calculated under the assumption that in the given region database 2 is considered to be more reliable than database 4 and therefore the weight of database 2 is 0.7 and the weight of database 4 is 0.3.

In principle, Fig. 4D shows the same situation as Fig. 4B. However, routes that are expected to be travelled by tracked objects are indicated (black lines) as well as a distribution center which is expected to process the tracked object (diamond shape). Taking into account this additional information, the tracking system may assume that the object is travelling on one of the routes or being processed by the distribution center. As an example, travelling on the route may be assumed if the determined estimate of location lies within a certain distance of the route (i. e. within the dash-dotted lines), whereas processing in the distribution center is assumed if the determined estimate of location lies within a certain distance of the distribution center (i. e. within the dash-dotted circle). In case every object travelling the route is expected to be processed in the distribution center, a position within the distribution center is assumed if according to the aforementioned criteria the object might be on the route as well as in the distribution center. In the case displayed in Fig. 4D the tracking system will determine that the object is within the distribution center as both estimates X and Y lie within the predetermined maximum distance of the center (dash-dotted circle).

The invention is not limited to the described embodiments. In particular, the described method and system may be used not only for tracking cellular devices (including cellular phones, dedicated tracking modules comprising a transceiver for communication with the cellular network, etc.) but also for other applications such as locating cellular devices in cases of emergency or criminal prosecution or obtaining statistical data for market research or network planning.

Furthermore, in addition to the coordinates obtained from cell plans based on an identification of the current cell of the cellular device further position dependent information including more accurate positioning information obtained from the network or other sources (including other kinds of networks such as Wifi) may be taken into account. As mentioned before, the identification of the current cell may be obtained from the cellular device instead of directly from the network management. Furthermore, the statistical processing of the coordinates may include further steps or work in a simplified manner (where e. g. always the centroid of all sets of coordinates is calculated or - in contrast - always only the set of coordinates relating to the data provider assumed to offer the most reliable result in the given region is used).

Further, the architecture of the system may be chosen differently from that of the described embodiment. In particular, several components of the system (such as parts of the tracking platform, the location interpreter and/or the signalling transfer gateway) may be integrated into one component, i. e. provided as a number of software modules.

In summary, it is to be noted that the invention provides a method and a system to determine the position of a cellular device that allows for reliably determining the position of cellular devices essentially independent of the location of the devices, i. e. substantially world-wide.

Claims

1. A method to determine the position of a cellular device, whereas the position is determined by a server distant from the cellular device, comprising the steps of

   a) providing the server with cell identification information identifying the current cell where the cellular device is actually logged in or was last seen;

   b) at least for a current cell not belonging to a network of a service provider of the cellular device and not belonging to a network of selected roaming partners of the service provider, the server using a software interface for connecting to a service provider independent external cell plan database for obtaining coordinates based on the cell identification information.

2. The method as recited in claim 1, characterized in that the cell identification information comprises a cell global identity.

3. The method as recited in claim 1 or 2, characterized in that the server is connected to a network management of the service provider and in that the server is provided with the cell identification information by the network management.

4. The method as recited in claim 3, comprising the step of the server making a request to the network management by providing a piece of information that uniquely identifies the cellular device, in particular the MSISDN in a GSM or UMTS mobile network.

5. The method as recited in claim 3 or 4, characterized in that in a GSM or UMTS mobile network the cell identification information is requested from a Home Location Register of the network management.

6. The method as recited in claim 5, characterized in that the server is automatically notified by the Home Location Register about a cell change of the cellular device.

7. The method as recited in one of claims 1 to 6, characterized in that a plurality of sets of coordinates from a plurality of cell plan databases is obtained and the plurality of sets of coordinates is statistically processed in order to obtain improved coordinates.

8. The method as recited in claims 2 and 7, characterized in that the statistical processing involves the step of disregarding one of the plurality of sets of coordinates if a Mobile Country Code of the cell global identity does not correspond to a country determined from the one of the plurality of sets of coordinates.

9. The method as recited in claim 7 or 8, characterized in that the statistical processing involves the step of disregarding one of the plurality of sets of coordinates if corresponding to a position that is significantly offset of positions of at least two other of the plurality of sets of coordinates.

10. The method as recited in one of claims 7 to 9, characterized in that the statistical processing involves a weighting of at least some of the plurality of sets of coordinates, whereas the weighting is based on quality data relating to the cell plan databases.

11. The method as recited in one of claims 1 to 10, characterized in that a plurality of successively obtained cell identification information is used by server for determining the position of the cellular device.

12. The method as recited in one of claims 1 to 11, characterized by the step of forcing a location update of the cellular device.

13. A method of tracking an object for an object tracking system comprising a tracking module including a cellular device and linked to the object to be tracked and a control

system, characterized in that the method as recited in any of claims 1 to 12 is used to determine the position of the cellular device, whereas the server is part of the control system.

14. The method as recited in claim 13, comprising the step of comparing the obtained coordinates and/or the determined position with expected positions of the tracked object.

15. A system to determine the position of a cellular device, comprising

a) a server distant from the cellular device,

b) an interface for connecting the server to a service provider independent external cell plan database,

whereas

c) the server receives cell identification information identifying the current cell where the cellular device is actually logged in or was last seen; and

d) at least for a current cell not belonging to a network of a service provider of the cellular device and not belonging to a network of selected roaming partners of the service provider, the server contacts the external cell plan database for obtaining coordinates based on the cell identification information.

16. The system as recited in claim 15, characterized in that the servier is connected to a network management of the service provider and in that the server receives the cell identification information from the network management.

17. The system as recited in claim 16, further comprising a signalling transfer gateway for connecting the server to the network management, the signalling transfer gateway being programmed to:

a) translate requests of the server into a protocol supported by the network management;

b) forwarding the translated requests to the network management;

c) receiving responses of the network management; and

d) forwarding at least some of the responses to the server.

18. The system as recited in claim 16 or 17, characterized in that in a GSM or UMTS mobile network the cell identification information is requested from a Home Location Register of the network management.

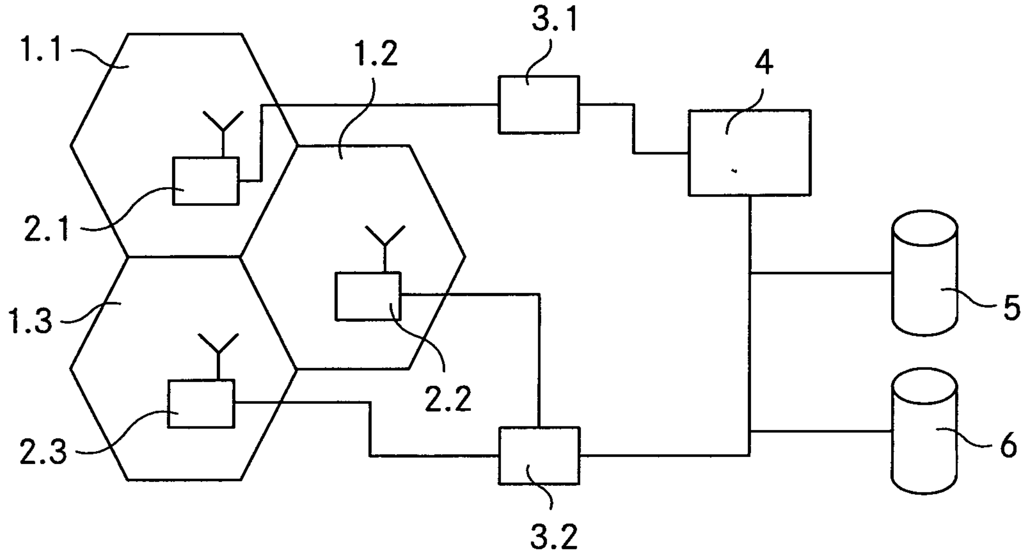
1.1
1.2
3.1
4
2.1
1.3
5
2.2
2.3
6
3.2

Fig. 1

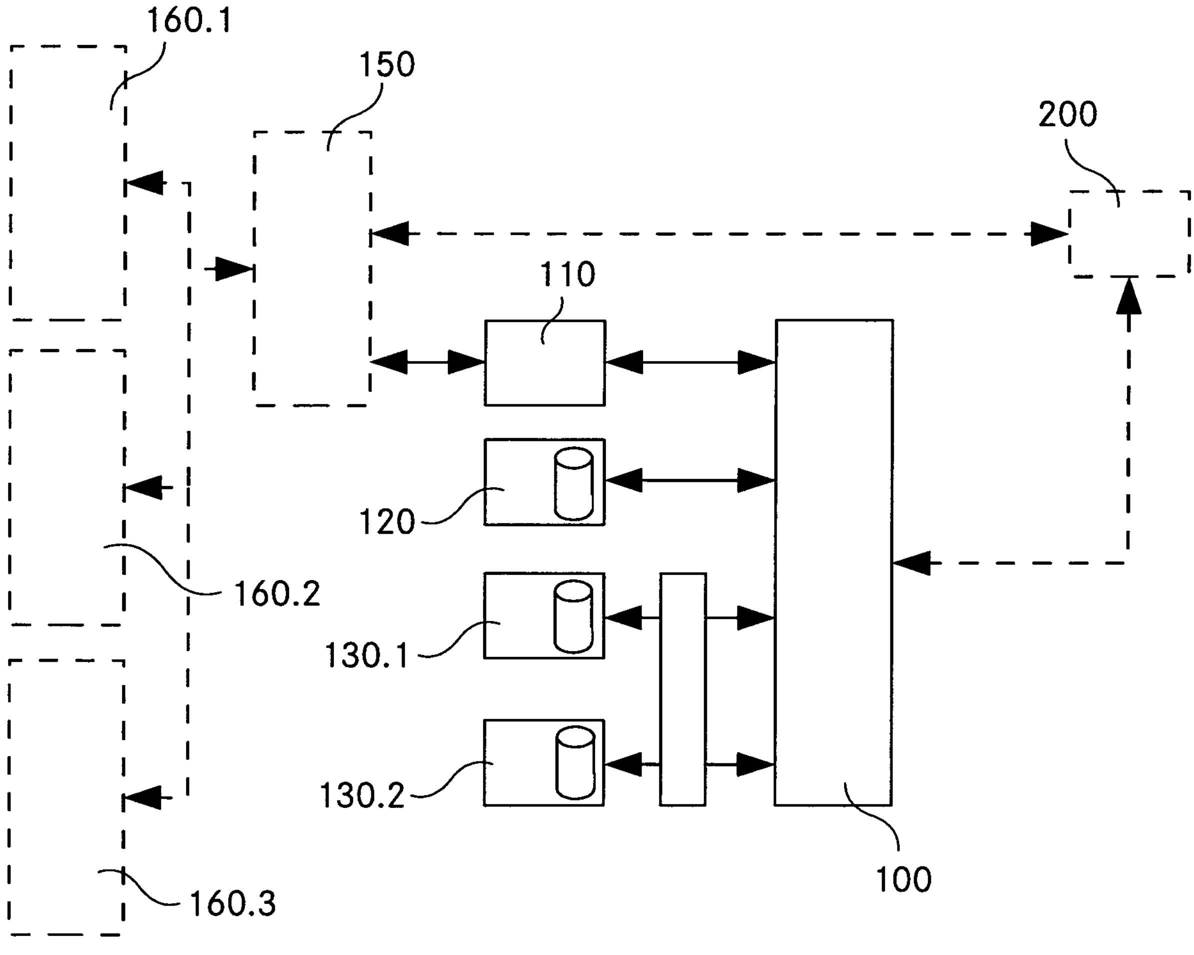
160.1
150
200
110
120
160.2
130.1
130.2
100
160.3

Fig. 2

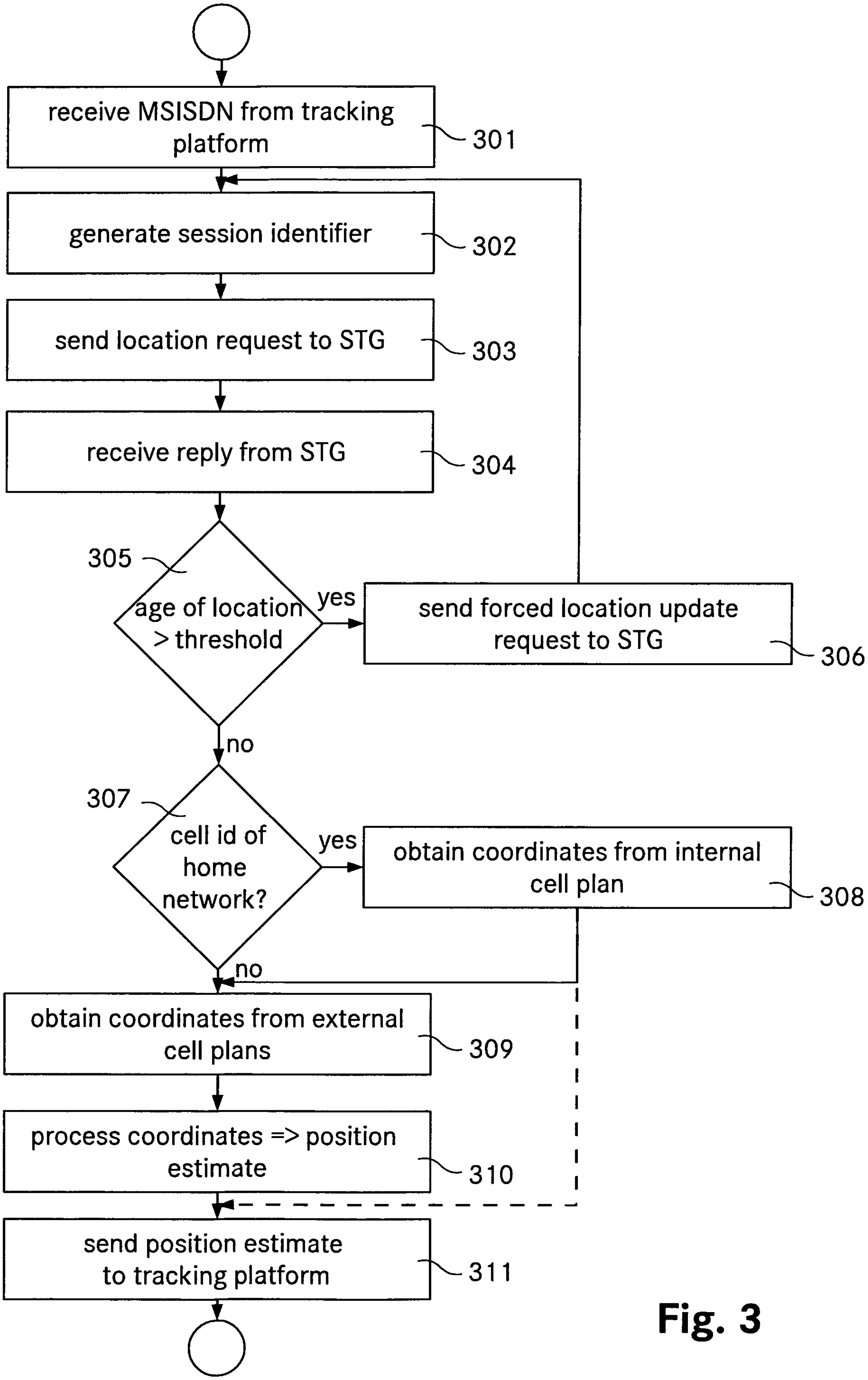
receive MSISDN from tracking platform
301
generate session identifier
302
send location request to STG
303
receive reply from STG
304
305
age of location > threshold
yes
send forced location update request to STG
306
no
307
cell id of home network?
yes
obtain coordinates from internal cell plan
308
no
obtain coordinates from external cell plans
309
process coordinates => position estimate
310
send position estimate to tracking platform
311

Fig. 3

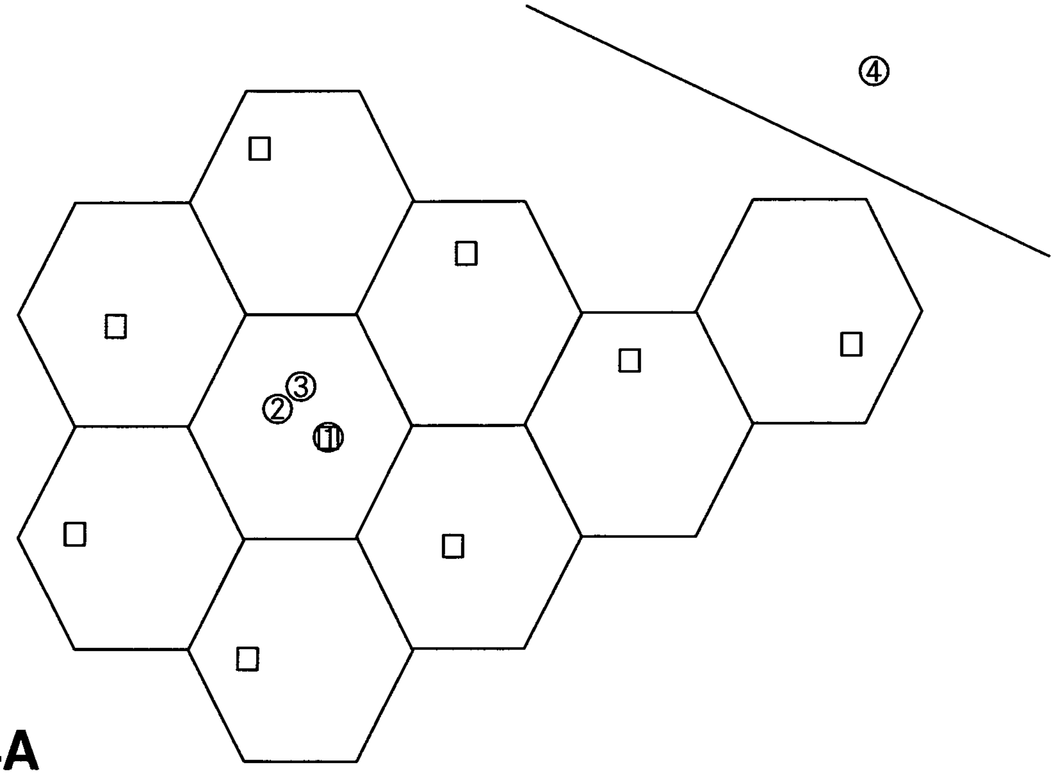

Fig. 4A

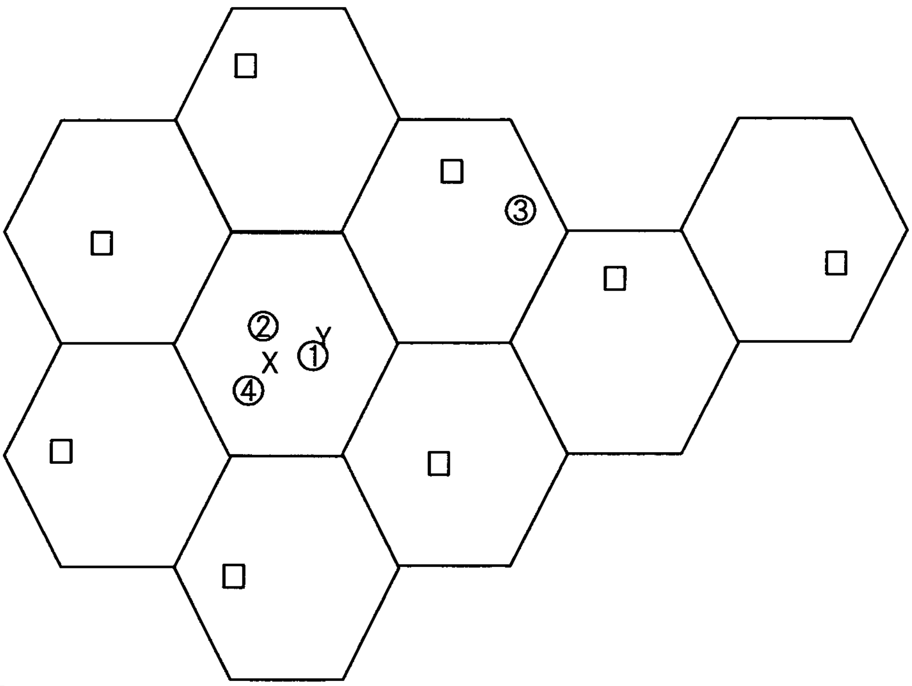

Fig. 4B

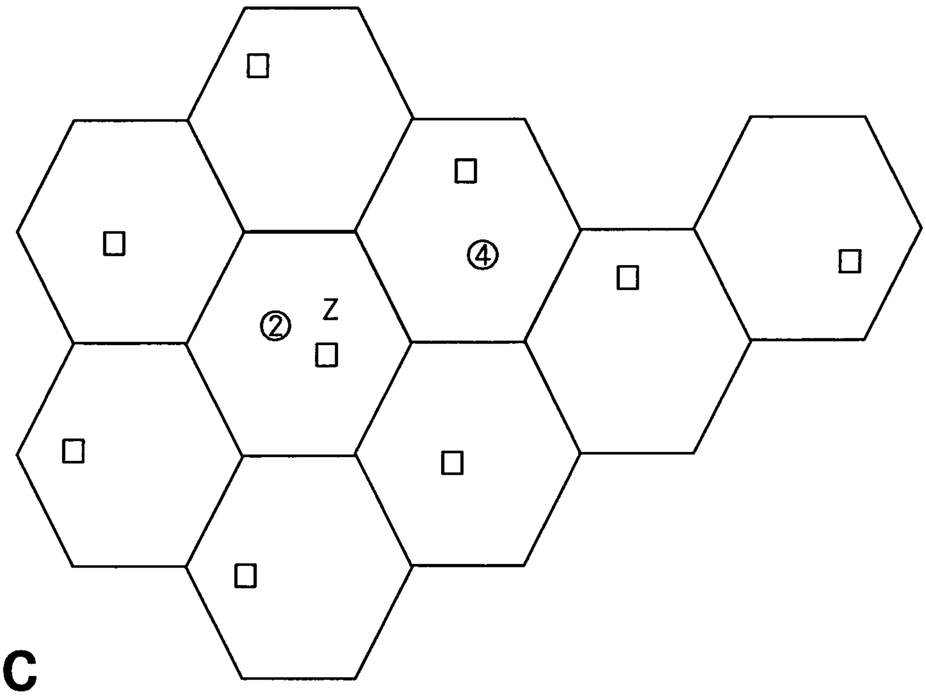

Fig. 4C

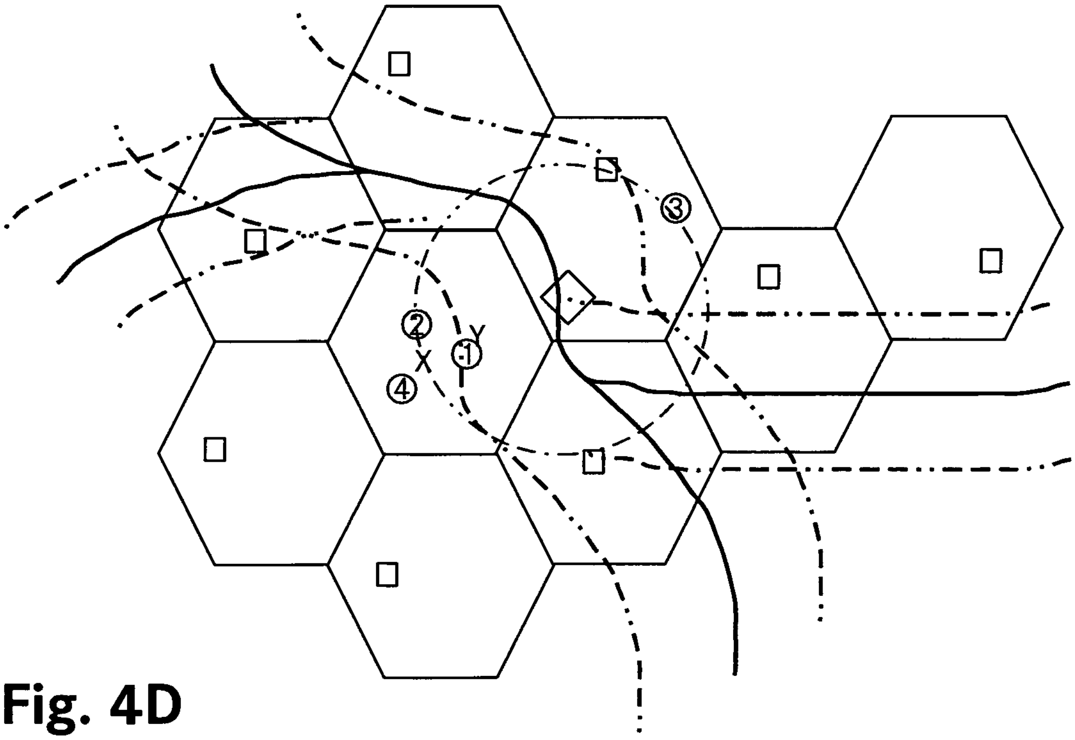

Fig. 4D

INTERNATIONAL SEARCH REPORT

International application No
PCT/CH2011/000147

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L29/08 H04W4/02 H04W64/00 H04W8/02 G01S5/02
G01S5/00 G06F17/30
ADD.

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)
H04L H04W H04Q G01S G06F

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, COMPENDEX, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 March 2012	05/04/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Losseau, Dominique

Form PCT/ISA/210 (second sheet) (April 2005)

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INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

International application No
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