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**(54) Title:** COOPERATION BETWEEN TWO METHODS FOR GEOLOCATING A TERMINAL OF A WIRELESS COMMUNICATION SYSTEM

**(54) Titre :** COOPÉRATION ENTRE DEUX MÉTHODES DE GÉOLOCALISATION D'UN TERMINAL D'UN SYSTÈME DE COMMUNICATION SANS FIL

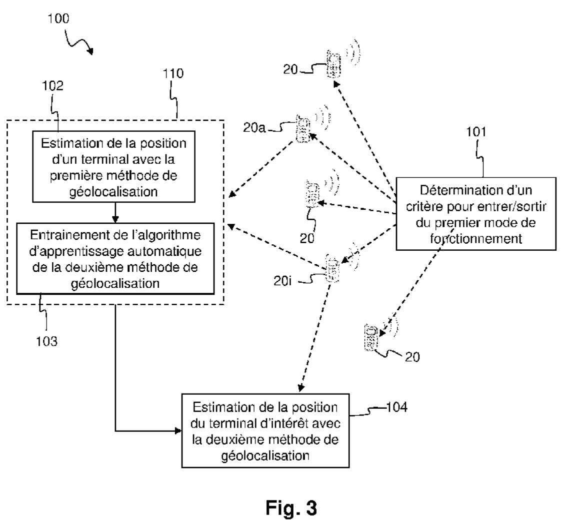


Fig. 3

101 Determining a criterion for entering/exiting the first operating mode
102 Estimating the position of a terminal using the first geolocation method
103 Training the machine learning algorithm of the second geolocation method
104 Estimating the position of the terminal of interest using the second geolocation method

**(57) Abstract:** The invention relates to a method (100) for geolocating a terminal (20i) by means of an access network of a wireless communication system. The invention is based on cooperation between a first geolocation method and a second geolocation method, as well as on control of an operating mode of the terminals (20). When a terminal (20, 20i) is configured in a first operating mode, it allows the access network to estimate (102) the position of the terminal using the first geolocation method. The positions estimated by the first geolocation method are used to train (103) the machine learning algorithm of the second geolocation method. It then becomes possible, once the algorithm has been trained, to estimate (104) the geographical position of a terminal (20i) even if this terminal is not in the first operating mode. The first geolocation method is more accurate than the second geolocation method, but it requires more power consumption and/or radio resources for the terminals (20).

**(57) Abrégé :** L'invention concerne un procédé (100) de géolocalisation d'un terminal (20i) par un réseau d'accès d'un système de communication sans fil. L'invention repose sur une coopération entre une première méthode de géolocalisation et une deuxième méthode de géolocalisation, ainsi que sur un contrôle d'un mode de fonctionnement des terminaux (20). Lorsqu'un terminal (20, 20i)) est configuré dans un premier mode de fonctionnement, il permet au réseau d'accès d'estimer (102) la position du terminal avec la première méthode de géolocalisation. Les positions estimées par la première méthode de géolocalisation permettent d'entrainer (103) l'algorithme d'apprentissage automatique de la deuxième méthode de géolocalisation. Il devient alors ensuite possible, une fois l'algorithme entrainé, d'estimer (104) la

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position géographique d'un terminal (20i) même si celui-ci n'est pas dans le premier mode de fonctionnement. La première méthode de géolocalisation est plus précise que la deuxième méthode de géolocalisation, mais elle nécessite une consommation énergétique et/ou des ressources radio plus importantes pour les terminaux (20).

# Cooperation between two methods for geolocating a terminal of a wireless communication system

## Field of the invention

The present invention belongs to the field of geolocating a terminal of a wireless communication system. The invention applies particularly well to the geolocation of IOT (Internet Of Things) or M2M (Machine-to-Machine) type connected objects.

## Prior art

There are currently many solutions for obtaining the geographical position of a terminal at an access network of a wireless communication system.

For example, the terminal may embed a GPS (Global Positioning System) receiver that allows it to determine its geographical position. The terminal can then transmit a message indicating this geographical position to the access network of the wireless communication system. Satellite geolocation is particularly accurate, but it is affected by a plurality of drawbacks, particularly the cost and the power consumption involved in integrating and using a GPS receiver in an object. Furthermore, transmitting a message including the geographical position of the terminal to the access network also has a negative impact on the power consumption of the terminal. This is particularly true for an IoT or M2M type communication system wherein a message transmitted by a terminal must be as short as possible due to significant constraints on the throughput and the power consumption. In addition, GPS type satellite geolocation methods are known to have relatively low response ratios in closed or covered areas (for example in hangars, buildings or densely forested areas). "Response ratio" means a ratio between the number of times where a position could be effectively determined in relation to the number of times where an attempt was made to determine a position.

Geolocation methods based on a database making the association between an identifier of a transmitter device (for example a WiFi or Bluetooth access point) and the geographical position of the transmitter device also exist. In such a method, a terminal detects an identifier of the transmitter device (the identifier is for example included in a message transmitted by the transmitter device on a beacon signal). The terminal can then transmit the identifier detected to the access network. The access network can subsequently query a geolocation server including a database with a table making the association between identifiers of transmitter devices and their respective geographical positions. The geolocation server can then determine the geographical position associated with said transmitter device, then send this information to the access network. The geographical position of the transmitter device corresponds to the estimated geographical position of the terminal. The geographical position of the terminal may possibly be refined depending on a signal strength indicator with which the beacon signal is received by the terminal. It is also possible to estimate the geographical position of the terminal depending on the geographical position of a plurality of neighboring transmitter devices of which the terminal has detected the identifiers. Nevertheless, these geolocation methods here again involve a significant power consumption of the terminals for listening to the beacon signals and for transmitting the identifiers of the neighboring transmitter devices detected. Moreover, these methods generally have relatively low response ratios in areas having a low density of population and/or of economic activity.

It is also known to estimate, at the access network, the geographical position of a terminal depending on messages transmitted by said terminal and received by one or more base stations of the access network. Such provisions particularly make it possible to save energy on the terminal side and to reduce the cost of the terminal by simplifying it (indeed, it is no longer necessary to integrate a GPS receiver or a WiFi or Bluetooth module at the terminal).

For example, when the same message is received by a plurality of base stations of in principle known geographical positions, then the geographical position of said terminal may be estimated by comparing the Received Signal Strength Indicators (RSSI) of the message on each of the base stations. Nevertheless, many parameters (obstacles, multiple trips, etc.) may influence the received signal strength indicator of the message by a base station, so that the geographical position thus estimated of the terminal is not always very accurate.

The geographical position of the terminal can also be estimated by comparing the Time of Arrival (TOA) and/or the Frequency of Arrival (FOA) of the message for various base stations. Nevertheless, this involves synchronizing in time and/or in frequency the base stations with one another, and the accuracy of estimating the geographical position depends on the accuracy with which the base stations are synchronized. For IoT and/or M2M type applications, it is not generally desirable to implement an accurate synchronization of base stations with one another because this would increase the complexity and the cost of manufacturing the access network.

Other geolocation methods are based on machine learning techniques. In concrete terms, this involves building, during a calibration phase, a database that associates with known geographical positions a radio signature corresponding to all of the RSSI measured for a terminal at a known position for a set of base stations of the system. Subsequently, during a search phase, a radio signature observed for a terminal located at a known position is compared to all of the signatures of the database in order to estimate the position of the terminal from the position(s) corresponding to the most similar signature(s). Nevertheless, these methods are generally affected by a lack of geolocation accuracy, and they have fairly significant constraints in terms of complexity (capacity and computing time), particularly in the case where the geographical area to be covered is vast. Furthermore, it is necessary to regularly carry out a calibration phase to keep the database up to date.

The patent applications US2022/053285A1, US2018/279251A1 and US2018/372854A1 each describe the use of a geolocation method based on machine learning to determine a geographical position from a radio signature. These documents also describe that this requires a calibration phase using another geolocation method.

**Disclosure of the invention**

The object of the present invention is to remedy all or some of the drawbacks of the prior art, particularly those disclosed above, by proposing a solution cooperating two different geolocation methods having advantages and drawbacks different from one another.

For this purpose, and according to a first aspect, the present invention proposes a method for geolocating a terminal, referred to as "terminal of interest", of a wireless communication system with an access network of said wireless communication system. The method comprises the following steps of:

- determining a criterion for making the terminal of interest enter and/or exit a first operating mode,
- estimating, for each of a plurality of messages received by the access network coming from the terminal of interest, and possibly coming from other terminals of the wireless communication system, a geographical position of the terminal at the origin of the message with a first geolocation method, each message of said plurality of messages being of a first type and being transmitted when the terminal at the origin of the message is in the first operating mode,
- training a machine learning algorithm of a second geolocation method from messages of the first type and associated geographical positions estimated using the first geolocation method, said machine learning algorithm being trained to

estimate the geographical position of a terminal from a message of a second type transmitted by the terminal when it is not in the first operating mode,

- once the machine learning algorithm of the second geolocation method has been trained, estimating the geographical position of the terminal of interest using the second geolocation method from a message of the second type transmitted by the terminal of interest.

The invention is based on cooperation between a first geolocation method and a second geolocation method, as well as on control of an operating mode of the terminals. When a terminal is configured in a first operating mode, it allows the access network to estimate the position of the terminal using the first geolocation method. The first geolocation method may particularly be based on determining, using a geolocation server, the geographical position of one or more neighboring transmitter devices (for example WiFi or Bluetooth access points) detected by the terminal. Nevertheless, other geolocation methods may be implemented as a first geolocation method. For example, the geographical position of a terminal may be determined by the terminal using a receiver of a satellite positioning system then transmitted to the access network. According to another example, the terminal may transmit to the access network measurements taken by the terminal using one or more sensors (accelerometer, gyroscope, magnetometer, altimeter, temperature or pressure sensor, etc.) in order to allow the access network to estimate the position of the terminal. According to yet another example, the terminal may explicitly transmit to the access network a time and/or a frequency of arrival of a radio signal received by the terminal (geolocation method based on TOA and/or FOA with measurements taken by the terminal).

The positions estimated by the first geolocation method are used to train the machine learning algorithm of the second geolocation method. It then becomes possible, once the algorithm has been trained, to estimate the geographical position of a terminal even if this terminal is not in the first operating mode.

The first geolocation method is generally more accurate than the second geolocation method. However, the first geolocation method generally requires a higher power consumption for the terminals. The second geolocation method may indeed be based on metadata associated with any message received coming from a terminal of which it is desired to estimate the geographical position. These metadata form a signature of the message. The signature includes for example, for each of a plurality of base stations of the access network, a feature related to the reception of said message by said base station (for example a signal strength indicator with which the message has been received by the base station). The signature is for example determined by a server of the access network connected to the various base stations. No particular operation specific to the geolocation is then required by the terminal for the second geolocation method (the message on which the second geolocation method is based may particularly have been sent with an aim other than that of geolocating the terminal, and the fact of sending a conventional message that does not have the primary objective of geolocating the terminal is not considered as an operation specific to the geolocation). A single message transmitted by the terminal may be received by a plurality of base stations, and this is what makes it possible to form the signature of the message.

It should be noted that the compromise between geolocation accuracy and power consumption is not necessarily the only compromise that may be taken into account to favor one or other of the two geolocation methods. Other criteria may be taken into account, such as for example the response ratio, the use of radio resources, etc.

The criterion for making the terminal of interest enter the first operating mode and/or for making the terminal of interest exit the first operating mode may be defined depending on whether an accurate position of the terminal of interest is required or depending on whether an approximate position of the terminal of interest is sufficient, according to the need for reducing the power consumption of the terminal of interest, according to the possibility or not of using the first geolocation method, according to the need or not for training the machine learning algorithm of the second geolocation method, depending on whether or not the terminal is in motion, etc.

In particular implementations, the invention may further include one or more of the following features, taken alone or according to any technically possible combinations.

In particular implementations, the message of the first type explicitly contains a parameter used by the first geolocation method.

This means for example that the message includes a set of bits coding the data carried by the message, and at least one part of said bits codes a parameter used by the first geolocation method. In other words, this means that the message includes at least one item of encoded information in the data of the message that contributes to determining the geographical position of the terminal.

Nevertheless, it should be noted that the first geolocation method may not require an explicit parameter, for example if the first method is based on a measurement by the access network of a time of arrival and/or of a frequency of arrival of the message for various base stations.

In particular implementations, the parameter is at least a part of an identifier of a transmitter device detected by the terminal at the origin of the transmission of the message of the first type.

The transmitter device corresponds for example to a WiFi or Bluetooth access point, or to an RFID (Radio Frequency Identification) tag.

In one variant, the parameter may also correspond to a geographical position determined by the terminal using a receiver of a GPS type satellite position system. According to another variant, the parameter may also correspond to a geographical position estimated by the terminal using measurements taken by one or more sensors of the terminal. According to yet another variant, the parameter may also correspond to a set of measurements taken by the terminal using one or more sensors (accelerometer, gyroscope, magnetometer, altimeter, temperature or pressure sensor, etc.). The parameter may also correspond to a time, a direction and/or a frequency of arrival of a radio signal received by the terminal (geolocation method based on TOA and/or FOA with measurements taken by the terminal).

In particular implementations, the message of the second type does not explicitly contain information used by the second geolocation method. In other words, this means that no information encoded in the data carried by the message of the second type is used by the second geolocation method.

In particular implementations, the machine learning algorithm is trained to associate a signature of a message with a geographical position. The signature includes, for each of a plurality of base stations of the access network, a feature related to the reception of said message by said base station.

In particular implementations, said feature related to the reception of a message by a base station is a measurement of a signal strength indicator with which said message is received by said base station.

In particular implementations, the transmission of a message of the second type requires fewer radio resources, and/or less electrical energy for the terminal of interest, than the transmission of a message of the first type.

In particular implementations, the criterion is defined by a configuration stored by the terminal of interest for making it enter and/or exit the first operating mode depending on predetermined time periods.

In particular implementations, the criterion for making the terminal of interest enter and/or exit the first operating mode depends on an indication provided by the sensor of the terminal of interest.

In particular implementations, the indication is related:

- to the beginning or to the end of a mobility phase of the terminal of interest, and/or

- to an alert triggered by the fact that a measurement taken by the sensor is greater than or less than a predetermined threshold, and/or
- to a detection of an impossibility of forming a message of the first type.

In particular implementations, the criterion for making the terminal of interest enter and/or exit the first operating mode is defined by the access network and sent to the terminal of interest by the access network in a configuration message on a downlink.

The configuration message makes it possible for example to make the terminal of interest enter the first operating mode during a learning period programmed by the access network. According to another example, the configuration message makes it possible to make the terminal of interest enter the first operating mode when it is desired to know its position with accuracy. According to yet another example, the configuration message may be transmitted to the terminal of interest depending on an estimation of a level of quality of geolocating said terminal by the second geolocation method, etc.

The configuration message may be sent by unicast or broadcast connection. Broadcast may be local to a particular geographical area.

According to a second aspect, the present invention relates to a computer-readable recording medium comprising instructions that, when they are executed by a computer cause it to implement the steps of the method according to any one of the preceding implementations.

According to a third aspect, the present invention relates to a server of an access network of a wireless communication system. The server is configured to:

- estimate, for each of a plurality of messages received by the access network coming from a terminal of interest, and possibly coming from one or more other terminals of the wireless communication system, a geographical position of the terminal at the origin of the message with a first geolocation method, each message of said plurality of messages being of a first type and being transmitted when the terminal at the origin of the message is in a first operating mode,
- train a machine learning algorithm of a second geolocation method from messages of the first type and associated geographical positions estimated using the first geolocation method, said machine learning algorithm being trained to estimate the geographical position of a terminal from a message of a second type transmitted by the terminal when it is not in the first operating mode,
- determine a criterion for making the terminal of interest enter and/or exit the first operating mode,

- send a configuration message to said terminal of interest for making it enter and/or exit the first operating mode depending on the criterion thus determined,
- once the machine learning algorithm of the second geolocation method has been trained, estimate the geographical position of the terminal of interest using the second geolocation method from a message of the second type transmitted by the terminal of interest.

In particular embodiments, the invention may further include one or more of the following features, taken alone or according to any technically possible combinations.

In particular embodiments, the message of the first type explicitly contains a parameter used by the first geolocation method.

In particular embodiments, the parameter is an identifier of a transmitter device detected by the terminal at the origin of the transmission of the message of the first type.

In particular embodiments, the message of the second type does not explicitly contain information used by the first geolocation method.

In particular embodiments, the machine learning algorithm is trained to associate a signature of a message with a geographical position, said signature including, for each of a plurality of base stations of the access network, a feature related to the reception of said message by said base station.

In particular implementations, said feature related to the reception of a message by a base station is a measurement of a signal strength indicator with which said message is received by said base station.

In particular embodiments, the criterion for making the terminal of interest enter and/or exit the first operating mode is determined depending on predetermined learning periods, or depending on a level of urgency for geolocating the terminal of interest, or depending on an estimation of a level of quality of geolocating said terminal of interest by the second geolocation method.

According to a fourth aspect, the present invention relates to an access network including a server according to any one of the preceding embodiments.

In particular embodiments, the access network is a low power wide area network.

According to a fifth aspect, the present invention relates to a Terminal of a wireless communication system, configured to:

- determine a criterion for entering and/or exiting a first operating mode,

- only when the terminal is in the first operating mode, transmit to the access network a message of a first type explicitly containing a parameter intended to be used by the access network to geolocate the terminal using a first geolocation method,
- when the terminal is not in the first operating mode, transmit to the access network a message of a second type that can be used by the access network to geolocate the terminal using a second geolocation method, the transmission of the message of the second type requiring fewer radio resources, and/or less electrical energy than the transmission of the message of the first type.

**Presentation of the figures**

The invention will be better understood upon reading the following description, given by way of non-limiting example, and referring to Figures 1 to 3 that show:

[Fig. 1] a schematic representation of an example of embodiment of a wireless communication system,

[Fig. 2] a schematic representation of an example of embodiment of a terminal,

[Fig. 3] a schematic representation of the main steps of one implementation of a method for geolocating a terminal.

In these figures, identical references from one figure to another designate identical or similar elements. For reasons of clarity, the elements shown are not necessarily to the same scale, unless otherwise specified.

**Detailed description of one embodiment of the invention**

Figure 1 schematically shows a wireless communication system 10, including terminals 20 and an access network 30 including a plurality of base stations 31.

The terminals 20 are adapted to transmit messages over an uplink to the access network 30. Each base station 31 is adapted to receive the messages from a terminal 20 when said terminal 20 is within its range. Conventionally, a message transmitted by a terminal 20 includes an identifier of the terminal 20. Each message received by a base station 31 is for example transmitted to a server 32 of the access network 30, possibly accompanied with other information such as an identifier of the base station 31 which received it, the received signal strength indicator of the message received, the time of arrival of said message the frequency at which the message was received, etc. The server 32 processes for example all of the messages received from the various base stations 31.

The wireless communication system 10 may be unidirectional, that is to say that it only makes it possible to exchange messages on the uplink from the terminals 20 to the access network 30. However, nothing prevents, according to other examples, the possibility of bidirectional exchanges. If applicable, the access network 30 is also adapted to transmit, by means of the base stations 31, messages on a downlink to the terminals 20, which are adapted to receive them.

The message exchanges on the uplink to the access network 30 use a first wireless communication protocol.

In particular embodiments, the first wireless communication protocol is a Low Power Wide Area Network (LPWAN) communication protocol. Such a wireless communication system is an access network with long range (greater than one kilometer, or even greater than ten or so kilometers), with low power consumption (for example a power consumption during transmission or reception of a message less than 100 mW, or even less than 50 mW, or even less than 25 mW), and of which the throughputs are generally less than 1 Mbits/s. Such wireless communication systems are particularly adapted for IoT or M2M type applications.

In an IoT or M2M type communication system, the data exchanges are essentially unidirectional, namely on an uplink from the terminals 20 to the access network 30 of the wireless communication system 10. In order to minimize the risks of losing a message transmitted by a terminal 20, the planning of the access network is often performed such that a given geographical area is simultaneously covered by a plurality of base stations 31, in such a way that a message transmitted by a transmitter device 20 may be received by a plurality of base stations 31.

In the remainder of the description, it is considered by way of non-limiting example that the first wireless communication protocol is an ultra narrow band and low power wide area network communication protocol. "Ultra Narrow Band" (UNB) means that the instantaneous frequency spectrum of the radio signals transmitted by the terminals is of frequency width less than two kilohertz, or even less than one kilohertz.

A terminal 20 is also adapted to receive messages transmitted by at least one transmitter device 40, which is in the vicinity of said terminal 20. The messages transmitted by the transmitter device 40 use a second wireless communication protocol, different from the first wireless communication protocol. It should be noted that the transmitter device 40 may be entirely independent of the wireless communication system 10, and there is no need to support the first wireless communication system.

In the example considered and illustrated in Figure 1, the terminal 20a is close to two transmitter devices 40 of which it can receive messages. The terminal 20i is close to another transmitter device 40 of which it can receive messages.

In particular embodiments, the second wireless communication protocol has a shorter range than the range of the first wireless communication protocol. However, it should be noted that it is also possible, according to other examples, to have a second wireless communication protocol of which the range is shorter than that of the first wireless communication protocol.

The second wireless communication protocol is for example a Wireless Local Area Network (WLAN) communication protocol, for example of the WiFi type (IEEE 802.11 standards), etc., or also a Wireless Personal Area Network (WPAN) communication protocol, for example of the Bluetooth or BLE (Bluetooth Low Energy) type, etc. According to yet another example, the second wireless communication protocol may be a near field communication protocol for example based on NFC (Near Field Communication) technology or on RFID (Radio Frequency Identification) technology.

A geolocation server 50 includes a database, referred to as "geolocation database", including a table storing transmitter device 40 identifiers. Each transmitter device 40 identifier is associated in the table with at least one item of position information representative of the geographical position of the transmitter device 40.

An identifier of a transmitter device 40 corresponds for example to a MAC (Media Access Control) address of the transmitter device 40. Other parameters may nevertheless act as identifiers for a transmitter device 40, such as for example an SSID (Service Set IDentifier) or a BSSID (Base Service Set Identifier) of a WiFi access point, an identifier of a Bluetooth or BLE access point, an identifier of an RFID tab, etc.

The position information may directly be coordinates (longitude, latitude and possibly altitude) of a geographical position of the transmitter device 40. The position information may nevertheless also be contextual information for estimating the geographical position of the transmitter device 40, such as for example a postal address, a store name, a district, region or country name, etc.

The geolocation server 50 is for example connected to the server 32 of the access network 30 by an Internet connection.

Figure 2 schematically shows an example of embodiment of a terminal 20.

As illustrated in Figure 2, the terminal 20 includes a first communication module 21 adapted to exchange messages with the base stations 31 according to the first wireless communication protocol. The first communication module 21 is for example in the form of a radio circuit including equipment (antenna, amplifier, local oscillator, mixer, analog filter, etc.).

The terminal 20 also includes a second communication module 22 adapted to receive messages transmitted by the transmitter device of interest 40, according to the second wireless communication protocol. The second communication module 22 is for example in the form of a radio circuit including equipment (antenna, amplifier, local oscillator, mixer, analog filter, etc.).

Furthermore, the terminal 20 also includes a processing circuit 23, connected to the first communication module 21 and to the second communication module 22. The processing circuit 23 includes for example one or more processing units and memory means (magnetic hard drive, electronic memory, optical disk, etc.) wherein a computer program product is stored, in the form of a set of program instructions to be executed in order to implement all or some of the steps of a method for geolocating the terminal (the geolocation method will be subsequently detailed with reference to Figure 3).

The server 32 of the access network 30 also includes one or more processing units and memory means wherein a computer program product is stored, in the form of a set of program code instructions to be executed in order to implement all or some of the steps of the method for geolocating a terminal.

The server 32 of the access network 30 is particularly configured to implement a first method for geolocating a terminal of interest 20i. In this first geolocation method, the terminal of interest 20i detects, for at least one neighboring transmitter device 40, an identifier of the transmitter device 40 (the identifier is for example included in a message transmitted by the transmitter device 40 on a beacon signal received by the terminal of interest 20i). The terminal of interest 20i can then transmit the identifier detected to the server 32 of the access network 30. The server 32 can then query the geolocation server 50. The geolocation server 50 can then determine the geographical position associated with said transmitter device 40, then send this information to the server 32 of the access network 30. The geographical position of the transmitter device 40 corresponds to an estimated geographical position of the terminal of interest 20i. The geographical position of the terminal may possibly be refined depending on a signal strength indicator with which the beacon signal is received by the terminal of interest 20i.

It is also possible, for this first geolocation method, to estimate the geographical position of a terminal depending on the geographical position of a plurality of neighboring transmitter devices 40 of which the terminal has detected the identifiers. This is the case for example for the terminal 20a in the example illustrated in Figure 1.

This first geolocation method can be repeated for various messages including one or more transmitter device 40 identifiers transmitted by the terminal of interest 20i and possibly by one or more other terminals 20, 20a of the wireless communication system 10.

A terminal 20 may be configured to enter a first operating mode and/or to exit the first operating mode. When a terminal 20 is in the first operating mode, the terminal 20 is configured to detect one or more neighboring transmitter device 40 identifiers and to transmit them in one or more messages to the access network 30.

A message sent by a terminal 20 to the access network 30 and including one part at least of a transmitter device 40 detected by said terminal 20 is a message of a first type. In the example considered, a message of the first type therefore explicitly contains a parameter used by the first geolocation method. This explicit parameter corresponds to at least a part of a transmitter device 40 identifier. It is for example coded on a set of bits. The transmission of a message of the first type by a terminal 20 has a negative impact on the power consumption of the terminal and on the use of radio resources (in the spectral domain and/or in the temporal domain) of the wireless communication system 10. Furthermore, when a terminal 20 is in the first operating mode, it consumes electrical energy to listen to the beacon signals of the transmitter devices 40 detected.

The server 32 of the access network 30 is also configured to implement a second method for geolocating a terminal of interest 20i. This second geolocation method is based on a machine learning algorithm trained to estimate the geographical position of the terminal of interest 20i from a message transmitted by said terminal of interest 20i and from a reference database built from messages of the first type and associated geographical positions estimated using the first geolocation method.

The reference database associates for example with each geographical position estimated using the first geolocation method a signature radio corresponding to the various signal strength indicators with which the message of the first type has been received by various base stations 31 of the access network 30.

Once the machine learning algorithm has been trained, it becomes possible to estimate the geographical position of the terminal of interest 20i using the second geolocation method. For this, a radio signature of interest is determined from a message transmitted by the terminal of interest. The radio signature of interest is subsequently compared with all of the signatures of the reference database. The geographical position of the terminal of interest 20i can then be estimated from the position(s) corresponding to the signature(s) of the reference database that most resembles the radio signature of interest.

The accuracy of the second geolocation method is generally of lower accuracy than the first geolocation method, particularly if the geographical area to be covered is vast and/or if the amount of data in the reference database is not high enough (nevertheless it should be noted, as indicated above, that the invention may also apply to a case where the geolocation method of the second method is just as good as, or even better than the accuracy of the first geolocation method).

Nevertheless, the second geolocation method has the advantage that any type of message transmitted by the terminal of interest 20i can be used to estimate the position of the terminal of interest 20i. In particular, this message does not need to explicitly contain information used by the second geolocation method. Indeed, in the example considered, the second geolocation method is based on the signal strength indicators with which the base stations 31 of the access network 30 have received the message, and not on an explicit item of information contained in the message. No particular operation specific to the geolocation is then required by the terminal of interest 20i for the second geolocation method (the message on which the second geolocation method is based may particularly have been sent with an aim other than that of geolocating the terminal). In order to estimate the position of the terminal of interest 20i, the second geolocation method may therefore be based on a message of a second type transmitted by the terminal of interest 20i when it is not in the first operating mode (nevertheless it should be noted that nothing prohibits from being able to send a message of the second type when the terminal is in the first operating mode). In the example considered, the transmission of a message of the second type requires fewer radio resources and less electrical energy for the terminal of interest 20i, than the transmission of a message of the first type.

Advantageously, the invention is based on controlling the first operating mode of the terminals 20 in order to advantageously make the first geolocation method and the second geolocation method cooperate. When a terminal is configured in a first operating mode, it allows the access network to estimate the position of the terminal using the first geolocation method. The positions estimated by the first geolocation method are used to train the machine learning algorithm of the second geolocation method. It then becomes possible, once the algorithm has been trained, to estimate the geographical position of a terminal even if this terminal is not in the first operating mode.

The criterion for making the terminal of interest enter the first operating mode and/or for exiting the terminal of interest 20i from the first operating mode may be defined for example depending on whether an accurate position of the terminal of interest 20i is required or depending on whether an approximate position of the terminal of interest 20i is sufficient. When an accurate position of the terminal of interest 20i is required, the terminal of interest 20i should be entered in the first operating mode so that it detects neighboring transmitter devices 40 and transmits the identifiers detected in order to allow accurate geolocation of the terminal of interest 20i using the first geolocation method. When an approximate position of the terminal of interest 20i is sufficient, the terminal of interest 20i should be exited from the first operating mode in order to save the power consumed by the terminal of interest 20i and/or optimize the use of radio resources of the communication system 10.

The criterion for making the terminal of interest enter and/or exit the first operating mode may also be defined according to the need for reducing the power consumption of the terminal of interest.

The criterion for making the terminal of interest enter and/or exit the first operating mode may also be defined according to the possibility or not of using the first geolocation method. For example, if it is known that the terminal of interest 20i may not be able to detect a neighboring transmitter device 40, the terminal of interest 20i should be exited from the first operating mode.

The criterion for making the terminal of interest 20i enter and/or exit the first operating mode may also be defined according to the need or not for training the machine learning algorithm of the second geolocation method. For example, if the amount of data in the reference database is not sufficient, or if there is a risk that these data are obsolete, then the terminal of interest 20i should be entered in the first operating mode so that it transmits messages of the first type that will make it possible to update the reference database.

The criterion for making the terminal of interest 20i enter and/or exit the first operating mode can be defined by a predetermined configuration stored by the terminal of interest 20i.

The criterion can particularly be defined depending on predetermined time periods. For example, the terminal of interest 20i may be configured to enter/exit the first operating mode at regular intervals, or at recurrent and increasingly less frequent intervals, etc.

According to another example, the criterion for making the terminal of interest 20i enter and/or exit the first operating mode depends on an indication provided by the sensor of the terminal of interest 20i. This indication may particularly be related to the beginning or to the end of a mobility phase of the terminal of interest 20i (it is for example interesting to favor an accurate geolocation by activating the first operating mode at the beginning or at the end of a mobility phase of the terminal). The sensor used to determine the beginning or the end of a mobility phase of the terminal of interest 20i may be an accelerometer. Indeed, it may be interesting to favor one or other of the two geolocation methods depending on whether or not the terminal of interest is in motion. In particular, in the example considered where the first geolocation method is based on a collaboration with transmitter devices, it may be advantageous to favor a geolocation via the first geolocation method when the terminal is immobile, and favor a geolocation via the machine learning algorithm of the second geolocation method when the terminal is in motion. According to another example, if the first geolocation method is based on a GPS receiver embedded in the terminal, it may be advantageous to favor a geolocation via the first geolocation method when the terminal is in motion, and favor a geolocation via the machine learning algorithm of the second geolocation method when the terminal is immobile.

This indication may also be related to an alert triggered by the fact that a measurement taken by the sensor is higher or lower than a predetermined threshold (need to obtain an accurate geolocation of the terminal by activating the first operating mode when an alert is detected).

The criterion for making the terminal of interest 20i enter and/or exit the first operating mode may also be defined by the access network 30 and sent to the terminal of interest 20i by the access network 30 in a configuration message on a downlink. The criterion may particularly be determined depending on predetermined learning periods, or depending on a level of urgency for geolocating the terminal of interest 20i, or depending on an estimation of a level of quality of geolocating the terminal of interest 20i by the second geolocation method (for example, if the accuracy is insufficient, the terminal should be entered in the first operating mode to obtain a more accurate geolocation of the first geolocation method, and/or to enrich the reference database of the second geolocation method).

The configuration message may be sent by unicast or broadcast connection. Broadcast may be local to a particular geographical area.

Figure 3 schematically shows the main steps of one example of implementation of a method 100 according to the invention for geolocating a terminal of interest 20i in a communication system 10 such as that described with reference to Figure 1.

The method 100 includes a step of determining 101 a criterion for making the terminal of interest 20i enter and/or exit a first operating mode, This criterion can be determined such as described above. The choice of a particular method for determining this criterion is only one variant of the invention.

The method 100 includes a step of estimating 102, for each of a plurality of messages received by the access network 30 coming from the terminal of interest 20i, and possibly coming from other terminals 20, 20a, a geographical position of the terminal at the origin of the message using the first geolocation method. Each message of said plurality of messages is a message of the first type transmitted when the terminal at the origin of the message is in the first operating mode.

The method 100 includes a step of training 103 the machine learning algorithm of the second geolocation method. This training is carried out from messages of the first type and associated geographical positions estimated using the first geolocation method. The machine learning algorithm is trained to estimate the geographical position of a terminal from any message transmitted by the terminal (and particularly a message of the second type that does not include explicit information for the geolocation). Furthermore, the machine learning algorithm may be trained to determine an accuracy with which the geographical position of the terminal has been estimated. This accuracy may in particular be used as a criterion for making the terminal of interest enter and/or exit the first operating mode.

Once the machine learning algorithm of the second geolocation method has been trained, the method 100 includes a step of estimating 104 the geographical position of the terminal of interest 20i using the second geolocation method. This estimation 104 may particularly be performed from a message of the second type transmitted by the terminal of interest 20i when it is not in the first operating mode.

The description above clearly illustrates that, with its various features and their advantages, the present invention achieves the objectives set. In particular, controlling the first operating mode of the terminals advantageously makes it possible to intelligently make the first geolocation method and the second geolocation method cooperate to reduce the power consumption of the terminals and/or the radio resources of the communication system.

It should be noted that the implementations and embodiments considered above have been described by way of non-limiting examples, and that other variants are consequently possible.

The present invention applies particularly advantageously, although not in a limiting way, to the geolocation of IoT or M2M type connected objects with an LPWAN type network. However, nothing prevents other types of Wireless Wide Area Networks (WWAN) from being considered. For example, the first wireless communication protocol may be a standardized communication protocol of the UMTS (Universal Mobile Telecommunications System), LTE (Long Term Evolution), LTE-Advanced Pro, 5G, type, etc.

The invention has been described by considering that the first method of for geolocating a terminal 20 is based on determining the geographical position of one or more neighboring transmitter devices 40 detected by the terminal using a geolocation server 50.

Nevertheless, other geolocation methods may be implemented as a first geolocation method. For example, the geographical position of a terminal 20 may be determined by the terminal using a receiver of a satellite positioning system then transmitted to the access network 30. According to another example, the terminal may transmit to the access network measurements taken by the terminal using one or more sensors (accelerometer, gyroscope, magnetometer, altimeter, temperature or pressure sensor, etc.) in order to allow the access network to estimate the position of the terminal. According to yet another example, the terminal may transmit to the access network a time and/or a frequency of arrival of a radio signal received by the terminal (geolocation method based on TOA and/or FOA with measurements made by the terminal).

It should also be noted that nothing imposes that the messages of the first type necessarily include an explicit parameter related to the geographical position of the terminal 20 (for example, if the first geolocation method is a geolocation method based on TOA and/or FOA with measurements taken by the access network 30).

The invention has been described by considering that the second geolocation method uses a machine learning algorithm based on radio signatures representative of the signal strength indicators with which a message is received by various base stations 31 of the communication system 10. Nevertheless, nothing would prevent the machine learning algorithm from being based on other features of a message transmitted by a terminal 20. For example, the following features may be taken into account: signal to noise ratio of the signal carrying the message, time or frequency for receiving the message at the various base stations, angle of arrival of the radio waves carrying the message, identifiers of the base station having received the message, etc.

In addition, various types of machine learning algorithms are possible. This may also concern classification algorithms as well as regression algorithms. The choice of a particular machine learning algorithm for the second geolocation method is only one variant of the invention.

It should also be noted that not all the terminals 20 of the communication system 10 necessarily need to support the first operating mode. Indeed, it is possible to train the machine learning algorithm of the second geolocation method with only one part of the terminals 20 of the access network 30 that support the first operating mode. As soon as the machine learning algorithm is trained, it becomes possible to geolocate a terminal that does not support the first operating mode using the second geolocation method.

As mentioned above, nothing prohibits from being able to send a message of the second type when the terminal is in the first operating mode. In addition, nothing prohibits from being able to estimate the position of a terminal using the second geolocation method by being based on a message of the first type transmitted by said terminal. In this case, it becomes possible to estimate the position of the terminal from the message of the first type not only using the first geolocation method, but also using the second geolocation method. Such provisions may make it possible to compare the estimated positions with each method in order to determine a more accurate position from two estimated positions, and/or to improve the accuracy of one or other of the methods, etc. Such provisions may also make it possible to improve the response ratio for the geolocation of the terminal (for example if in some cases only one of the two methods makes it possible to determine a position of the terminal, it is interesting to be able to estimate the position of the terminal with both methods).

**Claims**

1. Method (100) for geolocating a terminal (20), referred to as "terminal of interest" (20i) of a wireless communication system (10) with an access network (30) of said wireless communication system (10), said method (100) comprising:
   - determining (101) a criterion for making the terminal of interest (20i) enter and/or exit a first operating mode,
   - estimating (102), for each of a plurality of messages received by the access network (30) coming from the terminal of interest (20i), and possibly coming from other terminals (20, 20a) of the wireless communication system (10), a geographical position of the terminal at the origin of the message using a first geolocation method, each message of said plurality of messages being of a first type and being transmitted when the terminal at the origin of the message is in the first operating mode,
   - training (103) a machine learning algorithm of a second geolocation method from messages of the first type and associated geographical positions estimated using the first geolocation method, said machine learning algorithm being trained to associate a signature of a message with a geographical position, said signature including, for each of a plurality of base stations (31) of the access network (30), a feature related to the reception of said message by said base station (31), in order to be able to estimate the geographical position of a terminal from a message of a second type transmitted by the terminal when it is not in the first operating mode,
   - once the machine learning algorithm of the second geolocation method has been trained, estimating (104) the geographical position of the terminal of interest (20i) using the second geolocation method from a message of the second type transmitted by the terminal of interest (20i).

2. Method (100) according to claim 1 wherein data carried by the message of the first type encode information used by the first geolocation method.

3. Method (100) according to claim 2 wherein the parameter is at least a part of an identifier of a transmitter device (40) detected by the terminal (20a) at the origin of the transmission of the message of the first type.

4. Method (100) according to one of claims 1 to 3 wherein no information encoded in data carried by the message of the second type is used by the second geolocation method.

5. Method (100) according to one of claims 1 to 4 wherein said feature related to the reception of a message by a base station (31) is a signal strength indicator with which said message is received by said base station (31).

6. Method (100) according to one of claims 1 to 5 wherein the transmission of a message of the second type requires fewer radio resources, and/or less electrical energy for the terminal of interest (20i), than the transmission of a message of the first type.

7. Method (100) according to one of claims 1 to 6 wherein the criterion is defined by a configuration stored by the terminal of interest (20i) for making it enter and/or exit the first operating mode depending on predetermined time periods.

8. Method (100) according to one of claims 1 to 6 wherein the criterion for making the terminal of interest (20i) enter and/or exit the first operating mode depends on an indication provided by a sensor of the terminal of interest (20i).

9. Method (100) according to claim 8 wherein the indication is related:
   - to the beginning or to the end of a mobility phase of the terminal of interest (20i), and/or
   - to an alert triggered by the fact that a measurement taken by the sensor is greater than or less than a predetermined threshold, and/or
   - to a detection of an impossibility of forming a message of the first type.

10. Method (100) according to one of claims 1 to 9 wherein the criterion for making the terminal of interest (20i) enter and/or exit the first operating mode is defined by the access network (30) and sent to the terminal of interest (20i) by the access network (30) in a configuration message on a downlink.

11. Computer-readable storage medium comprising instructions that, when they are executed by a computer cause it to implement the steps of the method (100) according to any one of claims 1 to 10.

12. Server (32) of an access network (30) of a wireless communication system (10), said server (32) being configured to:
   - estimate, for each of a plurality of messages received by the access network (30) coming from a terminal of interest (20i), and possibly coming from one or more other terminals (20, 20a) of the wireless communication system (10), a geographical position of the terminal at the origin of the message with a first geolocation method, each message of said plurality of messages being of a first type and being transmitted when the terminal at the origin of the message is in a first operating mode,
   - train a machine learning algorithm of a second geolocation method from messages of the first type and associated geographical positions estimated using the first geolocation method, said machine learning algorithm being trained to associate a signature of a message with a geographical position, said signature including, for each of a plurality of base stations (31) of the access network (30), a feature related to the reception of said message by said base station (31), in order to be able to estimate the geographical position of a terminal from a message of a second type transmitted by said terminal when it is not in the first operating mode,
   - determine a criterion for making the terminal of interest (20i) enter and/or exit the first operating mode,
   - send a configuration message to said terminal of interest (20i) for making it enter and/or exit the first operating mode depending on the criterion thus determined,
   - once the machine learning algorithm of the second geolocation method has been trained, estimate the geographical position of the terminal of interest (20i) using the second geolocation method from a message of the second type transmitted by the terminal of interest (20i).

13. Server (32) according to claim 12 wherein data carried by the message of the first type encode information used by the first geolocation method.

14. Server (32) according to claim 13 wherein the parameter is an identifier of a transmitter device detected by the terminal (20a) at the origin of the transmission of the message of the first type.

15. Server (32) according to one of claims 12 to 14 wherein no information encoded in data carried by the message of the second type is used by the first geolocation method.

16. Server (32) according to claim 15 wherein said feature related to the reception of a message by a base station (31) is a signal strength indicator with which said message is received by said base station (31).

17. Server (32) according to one of claims 12 to 16 wherein the criterion for making the terminal of interest (20i) enter and/or exit the first operating mode is determined depending on predetermined learning periods, or depending on a level of urgency for geolocating the terminal of interest (20i), or depending on an estimation of a level of quality of geolocating said terminal of interest (20i) by the second geolocation method.

18. Access network (30) including a server (32) according to any one of claims 12 to 17.

19. Access network (30) according to claim 18, said access network (30) being a low power wide area network.

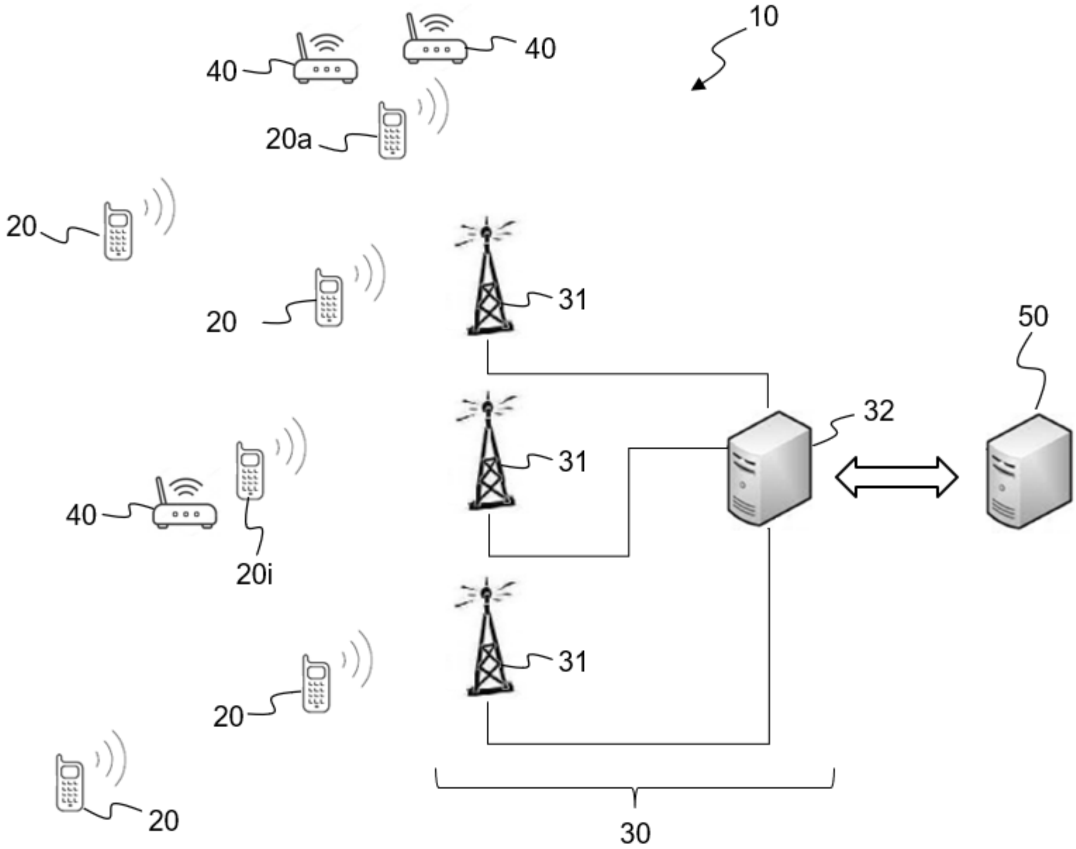


**Fig. 1**

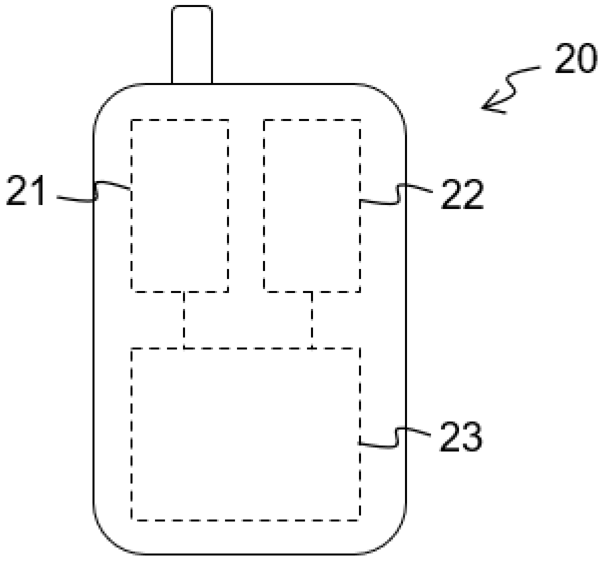


**Fig. 2**

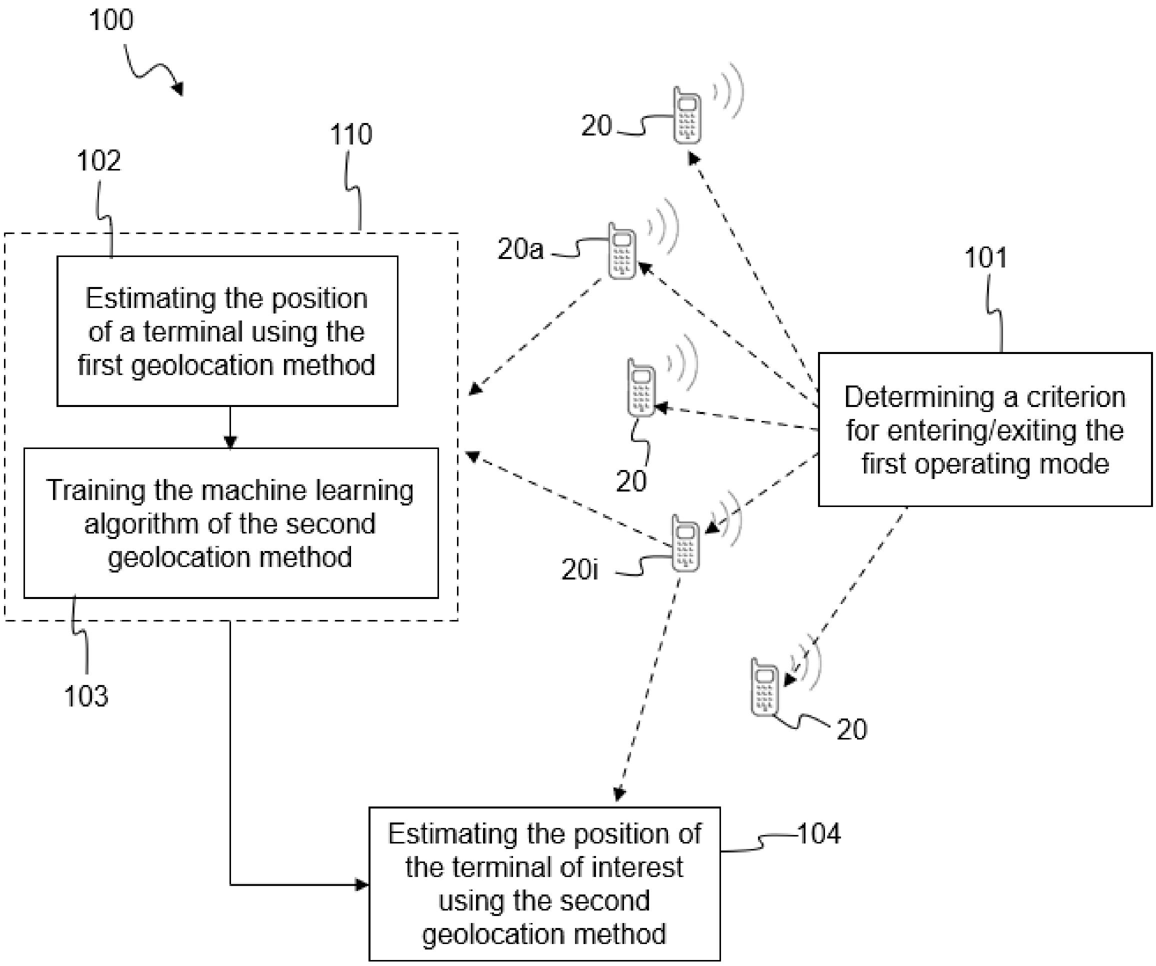
100
110
102
Estimating the position of a terminal using the first geolocation method
Training the machine learning algorithm of the second geolocation method
103
20
20a
20
20i
20
101
Determining a criterion for entering/exiting the first operating mode
Estimating the position of the terminal of interest using the second geolocation method
104

**Fig. 3**