

**Method for enhancing the reliability of the continuity of the
communications operated from a 4G mobile terminal linked to an IP
interconnection network**

The present invention relates to a method for guaranteeing with a high level of reliability the continuity of the communications operated from a fourth-generation (4G) mobile terminal linked to a level-3 interconnection network, in the terminology defined by the OSI ("Open Systems
5 Interconnection"). The invention applies notably to the mobility of mobile terminals in a context which is highly intolerant to faults, for example for networks used by military forces, public bodies, or civil agents such as the police, fire brigade or civil security. In particular, the invention may be
10 implemented in networks liable to experience breaks in communication links in the interconnection network.

The computerized networks used by fourth-generation (4G) mobile terminals comprise radio sub-networks, sometimes designated by the initials
15 RAN for "Radio Access Network", which are hooked up to an interconnection network, also called a CSN ("Connectivity Service Network"), the CSN being linkable to the Internet. A fourth-generation mobile terminal is identified by an IP ("Internet Protocol") address which allows it to receive and to send data across the whole of the computerized network. The mobile terminal is under
20 the coverage of an antennal station, also called a base station. A RAN is formed of a set of base stations whose coverages supplement one another so as to cover a territory. Between the mobile terminal and the base station, the data are transmitted in the form of radioelectric waves and then the base station transmits the data, generally via optical fibers or cables, to a gateway
25 interfacing between a RAN and a CSN. As a general rule, several base stations are controlled by one and the same control station. Such a control station fulfills several roles, notably the filtering of packets, the management of service quality, the authentication of users, the control of the base stations.

When the mobile terminal moves and exits the zone covered by a
30 first base station under the coverage of which it was situated, the communications are ensured by a second base station whose coverage is adjacent to the first. If the second base station is connected to the same

control station as the first base station, one speaks of micro-mobility. In the case where the mobile terminal moves to a second base station which is connected to a control station different from the first control station, the term macro-mobility is employed. The present invention deals more particularly with problems of continuity of communications within the framework of the macro-mobility of mobile terminals.

A protocol, called MIP for "Mobile IP", is known for managing the macro-mobility of mobile terminals on WiMax networks. MIP relies on the HA ("Home Agent") and FA ("Foreign Agent") functions which are software modules executed by routers at the level of the IP network layer (layer 3). The HA function makes it possible to receive and to steer data packets intended for the mobile terminal, including when the latter leaves its initial gateway. The FA function is executed by a router for relaying the data packets up to the mobile terminal. The HA function is an anchoring point for the mobile terminal in the CSN and this anchoring point persists as long as the mobile terminal is under the coverage of a RAN, whatever the base station to which it is connected. The HA function is generally executed by a single router of the CSN and thus constitutes a significant point of weakness. Hence, if a movement of the mobile terminal entails a change of control station, and if the router executing the HA function is not reachable from the new gateway — for example, if several communication links are cut —, the communication may not be maintained, despite the optional duplication mechanisms implemented. Hence, although the MIP protocol can constitute a solution in a centralized environment, it is not suited to networks with strong reliability constraints, such as for example private mobile radio or PMR.

A technique described in the French application published under the number FR2953357 has already been proposed for solving the problems of macro-mobility in a context of high reliability. However, this technique is less optimized when the interconnection network operates at the level of the IP layer, that is to say when the network uses IP routers rather than level-2 Ethernet switches.

An aim of the invention is to propose a reliable method for ensuring the continuity of communication of a mobile terminal moving around in a network comprising control stations linked by an interconnection network operating at the level of layer 3 of the ISO model. For this purpose, the

subject of the invention is a method for guaranteeing the continuity of the communications operated from a fourth-generation mobile terminal connected to a radio network provided with several base stations with which said terminal is able to communicate, a base station being affiliated to a controller from among several controllers linking said radio network to an interconnection network comprising routers operating at the level of the IP layer, at least one controller being connected to at least one gateway configured to encapsulate in IP packets all the IP packets arising from the radio network before broadcasting them over the interconnection network, the method being characterized in that it comprises at least the following steps:

- when a mobile terminal connects to a base station affiliated to a controller to which the mobile terminal was not affiliated hitherto, said controller transmits to a gateway a level-2 message comprising at least the IP address of the mobile terminal,
- said gateway creates, at the level of the IP layer, a message comprising the IP address of said mobile terminal and the IP address of said gateway in the interconnection network,
- said IP message is broadcast by said gateway to destination gateways associated with the other controllers, each of said destination gateways storing a correspondence between the IP address of the mobile terminal and the IP address of the sending gateway associated with the controller to which the mobile terminal is affiliated.

The method according to the invention makes it possible to permanently update the mobility management function, which is distributed throughout the network. Thus, if a control station becomes defective, only the sub-network of radio stations becomes inoperative, the other sub-networks of radio stations not being affected due to the fact that the mobility management function is ensured by each controller independently of one another. According to one embodiment, the level-2 message sent by the controller comprises a correspondence between the IP address of the mobile terminal and the level-2 address of said controller.

According to an implementation of the method according to the invention, the gateways are accessible through at least two different IP addresses, a first IP address being known to the nodes of the radio network,

a second IP address being known to the nodes of the interconnection network, in which all the IP packets arising from a controller are systematically transmitted to the gateway with which it is associated, said gateway encapsulating said IP packets in other IP packets whose destination
5 IP address is the second address of a destination gateway.

Thus in a communication between two mobile terminals each connected to a different base station, the stations being affiliated to different controllers, all the IP data packets transmitted by the first mobile terminal are encapsulated by IP packets of higher level in the gateway associated with the
10 first controller, these IP packets of higher level being transmitted to the gateway associated with the controller to which the second mobile terminal is affiliated. The IP packets are thereafter de-encapsulated, in such a way that the gateway associated with the second controller transmits the initial IP packets to the second controller, and then to the second mobile terminal.

15 According to an implementation of the method according to the invention, each controller is connected to a gateway specific to this controller. This gateway makes it possible at one and the same time to ensure the function for signaling the mobility of the mobile terminals, and also the function for guiding the IP data traveling through the interconnection network.

20 According to an implementation of the method according to the invention, each gateway is connected to the controller at which it is located by way of at least one IP router included in the interconnection network, said router being configured to systematically guide all the IP packets or level-2 messages to said gateway, prior to their encapsulation and broadcasting in
25 the interconnection network.

According to an implementation of the method according to the invention, after the encapsulation step, all the packets arising from a first gateway connected to a first controller travel via the interconnection network and are then transmitted to a second gateway connected to a second
30 controller, this second gateway removing the IP capsule added to the IP packets by the first gateway before transmitting said IP packets to the second controller.

According to an implementation of the method according to the invention, the first IP address known to the nodes of the radio network is the

same for all the gateways. The presence of these two IP addresses allows the mobile terminal to keep just a single IP address.

According to an implementation of the method according to the invention, when a router sends an ARP request to the interconnection
5 network, the first router of the interconnection network receiving said request transmits it to a gateway, said gateway transmitting a response to said router, the response comprising the level-2 address of said gateway.

The subject of the invention is also a system for guaranteeing the continuity of the communications operated from a fourth-generation mobile
10 terminal connected to a radio network provided with several base stations with which said terminal is able to communicate, said radio network being linked by controllers to an interconnection network comprising routers operating at the level of the IP layer, characterized in that each controller is connected to at least one gateway configured to encapsulate in IP packets all
15 the IP packets arising from the radio network before broadcasting them over the interconnection network.

According to one embodiment of the system according to the invention, at least one gateway is connected via a data bus to the controller with which it is associated.

20 According to one embodiment of the system according to the invention, at least one gateway is connected by way of at least one router to the controller with which it is associated.

Other characteristics will become apparent on reading the
25 nonlimiting detailed description given by way of example which follows in relation to appended drawings which represent:

- Figure 1, a diagram presenting an exemplary network on which the method according to the invention may be implemented;
- Figure 2, a diagram illustrating an exemplary path taken by data in a
30 network in which the method according to the invention is implemented;
- Figure 3, an example of macro-mobility handled by virtue of the method according to the invention.

Figure 1 is a view presenting an exemplary network on which the
35 method according to the invention may be implemented. A 4G

communications network 100 comprises a radio network 110 called a RAN subsequently, and an interconnection network 120 formed, for example, of cabled communications links or RF beam radio links or the like. In the example, the interconnection network 120 is linked to the Internet network 140 by way of a router 121. The RAN 110 comprises several radio base stations 111 spread out to cover a territory. Thus, the 4G communications network 100 allows mobile terminals 151 present in this territory to communicate with other terminals 152 connected to the 4G network 100 via other base stations. A mobile terminal 151, 152 is, for example, a telephone, a laptop computer or any other roaming apparatus able to communicate via the 4G network 100.

Several radio base station controllers 113a, 113b, 113c, 113d, also called more simply "controllers" subsequently, make it possible notably to manage the problems of macro-mobility of the mobile terminals, service quality, and authentication of users. Each of these controllers 113a, 113b, 113c, 113d controls one or more radio base stations 111. The functions traditionally allotted to the "Home agent" in the case of the use of the MIP (Mobile IP) protocol are, within the framework of the invention, distributed at the level of the base controllers 113a, 113b, 113c, notably so as to avoid the vulnerability of a centralized system. Furthermore, the controllers 113a, 113b, 113c, 113d are linked together by a network of routers 131, 132, 133, 134, 135 operating at the level of the IP layer.

Hence, when a new mobile terminal 151 connects to a base station 111 affiliated to a controller 113a to which this terminal 151 was not hitherto affiliated — stated otherwise, the mobile terminal was not connected to a base station affiliated to this controller 113a —, the other controllers 113b, 113c, 113d must be advised of the arrival of the new mobile terminal 151. In the example, the controller 113a is designed to be hooked up to an interconnection network comprising switches operating at level 2 of the ISO layer, although in the invention, this controller is hooked up to a network of routers 131, 132, 133, 134, 135 operating at level 3. The base controller 113a to which the new mobile terminal 151 is affiliated is configured to send a message to advise the other controllers 113b, 113c, 113d of the arrival of the mobile terminal 151. According to one mode of implementation of the method according to the invention, the message is of "Gratuitous ARP" or

GARP type. This message comprises the IP address of the mobile terminal and the level-2 address of the controller 113a, which in the case of an Ethernet network is an MAC address. In the implementation of the invention, the interconnection network 120 being level 3, the network cannot propagate
5 the GARP message automatically to the other controllers 113b, 113c, 113d. To allow the propagation of this message, gateways 141, 142, 143, 144 operating at the level of the IP layer are interfaced between each controller 113a, 113b, 113c, 113d and the interconnection network 120. The gateway 141, 142, 143, 144 is accessible to the controller 113a, 113b, 113c, 113d via
10 one or more routers 131, 132, 133, 134 of the interconnection network 120. The GARP message sent by the controller 113a with which the mobile terminal is newly affiliated is redirected to the gateway 141 which is associated with this controller 113a. This level-2 GARP message can thus be processed by the gateway 141 associated with the base controller 113a to
15 which the new mobile terminal 151 is affiliated. The gateway 141 utilizes level-2 message to create an IP message so as to alert the other gateways 142, 143, 144 of the arrival of a new mobile terminal 151 at the controller 113a associated with this gateway 141. The IP message propagates through the interconnection network 120 so as to reach the other gateways 142, 143,
20 144, which store a correspondence between the IP address of the mobile terminal and the IP address of the gateway 141 with which the controller 113a of the mobile terminal is affiliated. Thus, it is not necessary to directly alert the other controllers 113b, 113c, 113d of the arrival of a new mobile terminal 151 affiliated to the first controller 113a. It is the gateways 141, 142,
25 143, 144 which maintain this information necessary for proper management of the macro-mobility of the terminals 151. In the case of a movement of a mobile terminal, previously affiliated to a first controller, to a base station affiliated to another controller, the correspondence, maintained by each of the gateways 141, 142, 143, 144, between the IP address of the mobile
30 terminal and the IP address of the gateway associated with the controller to which this mobile terminal is affiliated is modified by each of the gateways 141, 142, 143, 144. Indeed, the IP address of the initial gateway is replaced with the IP address of the new gateway. Within this framework, the gateways play a role in signaling the mobility of the terminals.

The mobile terminals 151, 152 connected to the interconnection network 120 via the radio base stations 111 and the controllers 113a, 113b, 113c, 113d belong to the same IP sub-network, so that once a mobile terminal has been declared at the 4G network 100, and an IP address has been allocated to it, this IP address does not change, even in the case of macro-mobility of this terminal.

To allow the mobile terminals to pass from one controller to the other without changing IP address and without disturbing the communications, all the IP data packets transmitted through a controller 113a, 113b, 113c, 113d destined for another controller 113a, 113b, 113c, 113d are systematically encapsulated in other IP packets so as to be able to be propagated by the routers 131, 132, 133, 134, 135 of the interconnection network 120. A known IP address of the interconnection network 120 is allocated to the IP packets encapsulating the IP data packets, so as to correctly route them up to the destination controller, that is to say up to the controller charged with transmitting the packets to the base station to which the destination mobile terminal is connected. The IP capsule which had been added before routing in the interconnection network is thereafter removed at the level of this destination controller, more exactly by the gateway associated with this destination controller.

This IP in IP encapsulation mechanism is advantageously implemented by a gateway 141, 142, 143, 144 such as described above, a gateway preferably being put in place for each controller 113a, 113b, 113c, 113d. A gateway may be viewed, for the processing of IP data, as a means for encapsulating IP packets in other IP packets of higher level. Two IP addresses are allocated to each of the gateways 141, 142, 143, 144: a first IP address viewed from the radio network 110, and a second IP address viewed from the interconnection network 120. The first IP address, viewed from the radio network 110, is always the same, whatever the gateway 141, 142, 143, 144; stated otherwise, all the gateways have the same first IP address, which in Figure 1 is designated by "IP0". The second IP address, specific to each gateway, allows the addressing of the data within the interconnection network 120.

In the example of Figure 1, a router 131, 132, 133, 134 is interfaced between each controller 113a, 113b, 113c, 113d and the gateway

141, 142, 143, 144 with which it is associated. This router 131, 132, 133, 134 is configured to systematically transfer all the packets received from the controller to which it is connected to the associated gateway. All the packets entering the interconnection network 120 via a controller 113a, 113b, 113c, 113d are therefore transmitted to the gateway associated with this controller,
5 so as to perform the IP in IP encapsulation described above.

Advantageously, a gateway 141 is co-located with the router with which it is associated 131. According to one mode of implementation of the method according to the invention, the controller and the gateway are
10 physically integrated into the same machine, the gateway being for example connected to the controller by a network cable or a data bus.

Furthermore, certain gateways 145 of the interconnection network 120 can receive requests of ARP (Address Resolution Protocol) type sent from external routers 121 to this interconnection network 120. These
15 requests originate, for example, from external routers 121 charged with determining which MAC address in the interconnection network 120 is the one which corresponds to a determined IP address. These gateways 145 are configured to respond with their own MAC addresses; stated otherwise, to indicate to the external routers 121 that whatever the specified IP address
20 whose corresponding level-2 party is sought, it is the gateway 145 which must receive all the packets so as to undertake an IP in IP encapsulation such as described above and then steer them to the correct gateways of the network.

25 Figure 2 illustrates by a diagram an exemplary path taken by data in a network in which the method according to the invention is implemented. The figure illustrates with an arrowed line a path 201 followed by data between a first mobile terminal 151 and a second mobile terminal 152, the mobile terminals 151, 152 having been registered beforehand with the
30 controllers 113a, 113b.

The IP data arising from the first mobile terminal 151 are transmitted to a base station 111a, and then to the first controller 113a interfaced with the interconnection network 120. A router 131 of the interconnection network receives the data; it is configured to steer the data
35 packets automatically to the first gateway 141. This gateway 141, which

comprises two IP addresses as described above, encapsulates the IP data packets in other IP packets of higher level. The destination IP address in the interconnection network 120 which is allocated to the IP packets of higher level is the IP address of the destination gateway 142 viewed from the interconnection network 120. The IP packets of higher level are thus routed through the interconnection network 120 up to the destination gateway 142, which decodes the previously encapsulated IP data packets, and transmits them to the second controller 113b. The IP data are thereafter transmitted to a base station 111b and then to the second mobile terminal 152.

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Figure 3 illustrates an example of macro-mobility handled by virtue of the method according to the invention. The example of Figure 3 again employs the network of Figure 2, in which two mobile terminals 151, 152 communicate.

15 The second terminal 152 moves away from the base station 111b with which it was connected, until it connects to a base station 111d affiliated to a third controller 113d different from the previous controller. The second mobile terminal 152 is detected by the third controller 113d. A level-2 message 302 is sent by this third controller 113d to the gateway 144 with which it is associated, which gateway sends an IP message 303 (represented dashed in Figure 3) destined for the other gateways 141, 142, 143 to advise them of the movement of the mobile terminal 152. The tables of correspondences maintained by the gateways 141, 142, 143 are updated, so that the IP packets intended for the mobile terminal 152 are properly conveyed to the gateway 144 associated with the new controller 113d to which the second mobile terminal 152 is affiliated.

25 The path 301 followed by data between the first mobile terminal 151 and the second mobile terminal 152 after macro-mobility is illustrated by an arrowed solid line.

30 If one or more communication links are cut, then the meshed character of the network and the fact that each gateway has direct access to the correspondences between IP addresses of the mobile terminals and IP addresses of the gateways with which they are affiliated makes it possible to ensure the conveying of the data correctly. The mobility management function is decentralized.

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An advantage of the method according to the invention is that it makes it possible to reuse controllers initially designed to operate at level 2 of the ISO layer. It is thus possible to realize a reliable 4G network on the basis of a level-3 interconnection network. The method according to the invention
5 does not require the implementation of particular functionalities on the mobile terminals. Standard mobile terminals can therefore benefit from the invention. Finally, the method according to the invention is compatible with the conventional IP routing solutions and relies only on functions implemented in the controllers between the radio access network and the interconnection
10 network.

CLAIMS

1. Method for guaranteeing continuity of communications operated from several fourth-generation mobile terminals connected to a radio network provided with several base stations with which each of said several fourth-generation mobile terminals is configured to communicate, wherein each said base station is connected to a controller from among several controllers linking said radio network to an interconnection network comprising routers operating at an IP layer level, wherein said controllers are connected to at least one gateway from among a plurality of gateways, wherein each of said plurality of gateways is connected to at least one of said routers, wherein each of said at least one gateway has at least two different IP addresses, of which a first IP address is known to the fourth-generation mobile terminals of the radio network and of which a second IP address is known to the routers of the interconnection network, wherein said first IP address is the same for all the plurality of gateways of the radio network, and wherein each fourth-generation mobile terminal is associated with at least one base station and with at least one gateway connected to the controller to which said at least one base station is connected, wherein the method comprises, for each of said plurality of gateways, the establishment of a match list between the IP address of each fourth-generation mobile terminal connected to the radio network and said second IP address of said associated gateway, by performing at least the following steps:
 - when a particular fourth-generation mobile terminal connects to a particular base station connected to a first controller to which the particular fourth-generation mobile terminal was not affiliated previously, said first controller transmits to said gateway it is connected to a level-2 message comprising at least the IP address of said fourth-generation mobile terminal,
 - said gateway creates an IP message comprising the IP address of said particular fourth-generation mobile terminal and the second IP address of said gateway in the interconnection network, and
 - said IP message is broadcasted by said associated gateway to destination gateways associated with the other controllers, wherein each of said destination gateways stores a correspondence list between the IP address of the particular fourth-generation mobile terminal and the second IP address of the associated gateway,wherein the method also comprises routing IP packets in the interconnection network by performing at least the following steps:
 - all the IP packets arising from a controller are systematically transmitted to said associated gateway,

- said associated gateway encapsulates each of said IP packets to an IP packet of a higher level using said match list, wherein the IP destination address is the second IP address corresponding to a destination gateway.
2. Method according to Claim 1 wherein the controllers manage the problems of macro-mobility of the mobile terminal, service quality, and authentication of an user of the mobile terminal.
 3. Method according to Claim 1 wherein the controllers manage authentication of a user of the mobile terminal.
 4. Method according to any one of Claims 1 to 3, wherein each controller is connected to a gateway specific to this controller.
 5. Method according to Claim 4, in which each gateway is connected to the controller at which it is located by way of at least one IP router included in the interconnection network, said router being configured to systematically guide all the IP packets or level-2 messages to said gateway, prior to their encapsulation and broadcasting in the interconnection network.
 6. Method according to Claim 4 or claim 5, in which, after the encapsulation step, all the packets arising from a first gateway connected to a first controller travel via the interconnection network and are then transmitted to a second gateway connected to a second controller, this second gateway removing the IP capsule added to the IP packets by the first gateway before transmitting said IP packets to the second controller.
 7. Method according to any one of Claims 1 to 3, in which, when a router sends an ARP request to the interconnection network, the first router of the interconnection network receiving said request transmits it to a gateway, said gateway transmitting a response to said router, the response comprising the level-2 address of said gateway.
 8. System for guaranteeing continuity of communications operated from several fourth-generation mobile terminals connected to a radio network provided with several base stations with which each of said several fourth-generation mobile terminals is configured to communicate, wherein each said base station is connected to a controller from among several controllers linking said radio

network to an interconnection network comprising routers operating at an IP layer level, wherein said controllers are connected to at least one gateway from among a plurality of gateways, wherein each of said plurality of gateways is connected to at least one of said routers, wherein each of said at least one gateway has at least two different IP addresses, of which a first IP address is known to the fourth-generation mobile terminals of the radio network and of which a second IP address is known to the routers of the interconnection network, wherein said first IP address is the same for all the plurality of gateways of the radio network, and wherein each fourth-generation mobile terminal is associated with at least one base station and with at least one gateway connected to the controller to which said at least one base station is connected, wherein each of said plurality of gateways establishes a match list between the IP address of each fourth-generation mobile terminal connected to the radio network and said second IP address of said associated gateway by :

- when a particular fourth-generation mobile terminal connects to a particular base station connected to a first controller to which the particular fourth-generation mobile terminal was not affiliated previously, said first controller transmits to said gateway it is connected to a level-2 message comprising at least the IP address of said fourth-generation mobile terminal,
- said gateway creates an IP message comprising the IP address of said particular fourth-generation mobile terminal and the second IP address of said gateway in the interconnection network, and
- said IP message is broadcasted by said associated gateway to destination gateways associated with the other controllers, wherein each of said destination gateways stores a correspondence list between the IP address of the particular fourth-generation mobile terminal and the second IP address of the associated gateway,

wherein the IP packets are routed in the interconnection network by :

- transmitting all the IP packets arising from a controller to said associated gateway,
- said associated gateway encapsulate each of said IP packets to an IP packet of a higher level using said match list, wherein the IP destination address is the second IP address corresponding to a destination gateway.

9. System according to Claim 8, in which at least one gateway is connected via a data bus to the controller with which it is associated.

10. System according to Claim 8, in which at least one gateway is connected by way of at least one router to the controller with which it is associated.