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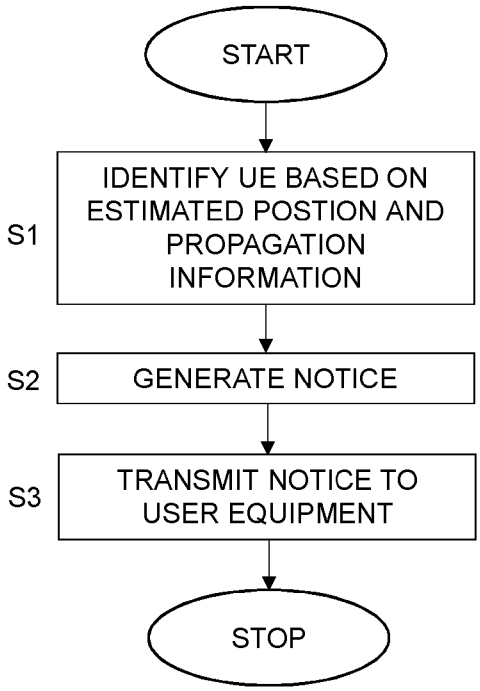

Fig. 1

(57) Abstract: Persistent poor radio signal propagation is managed within a radio-based communication network (1) by identifying a user equipment (5) based on an estimated position thereof within a cell (3) served by a radio base station (2) in the radio-based communication network (1) and based on propagation information defining a geographical area (4) within the cell (3) and where this geographical area experiences persistent poor radio signal propagation. A notice is generated and transmitted to the user equipment (5) to inform the user equipment (5) or a user thereof of the persistent poor radio signal propagation.

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INFORMING A USER EQUIPMENT ABOUT ITS ENTRANCE IN A GEOGRAPHICAL ZONE WITH POOR RADIO CONDITION

TECHNICAL FIELD

The present embodiments generally relate to quality of service improvement in radio-based communication networks, and in particular to quality of service improvement by management of persistent poor radio signal propagation in radio-based communication networks.

BACKGROUND

It is well known that radio-based communication networks do not provide uniform quality of service throughout all geographical area. Radio coverage problems may occur in such radio-based communication networks due to poor radio signal propagation caused by, for instance, static obstacles, such as buildings or tunnels; landscape obstacles, such as hills or mountains; insufficient provisioning of radio base stations and other network nodes; and/or specific network node problems, such as misconfiguration or hardware/software failures. Obviously such poor radio coverage conditions affect the experience of end users. Notably, the radio coverage problem often has similar effects on a plurality of end users.

Handover, also referred to as handoff, is the most common way to switch cell or radio channel for better quality of service. It refers to the process of transferring an ongoing call or data session from one cell to another cell, i.e. inter-cell handover, or from one radio channel to another radio channel within a same cell, i.e. intra-cell handover. Adjacent cells are assigned different radio frequencies to avoid interference or cross talk. Accordingly, during the handover, the user equipment will be transferred from one radio channel to another radio channel.

There are several approaches to initiate handover in the radio-based communication networks. *International Journal of Computer Applications* 21(2): 28-37, 2011 provides an overview of handover initiation and handover types. Two of the most common handover initiations are denoted relative signal strength (RSS) with threshold and RSS with hysteresis and threshold.

Briefly, RSS with threshold initiates handover of a user equipment if the current signal strength from a radio base station (RBS) in the current or serving cell is lower than a defined threshold and the signal strength from a RBS of a neighboring cell is stronger than the current signal strength. RSS with hysteresis and threshold initiates handover of a user equipment only if the current signal strength from

the RBS in the serving cell is lower than the defined threshold and the signal strength from the RBS in the neighboring cell is stronger than the current signal strength by a hysteresis margin.

However, the handover procedures and the handover initiations of prior art are marred by shortcomings. For instance, the trigger of handover, i.e. the defined threshold, is static. This means that handover initiation is always performed based on the actual value of the defined threshold without any further consideration of context. For example, if a user is watching streamed video at the edge of the serving cell and the defined threshold is set too low, then the user will suffer bad streaming quality. In such a situation it would have been more appropriate to use a higher defined threshold in order to initiate handover of the user equipment to the neighboring cell that provides stronger signal strength.

Furthermore, the prior art handover-based procedures require that the user equipment monitor the signal strength from not only the serving cell but also from neighboring cells. This drains the battery of the user equipment.

There is, thus, a need for improvements in quality of service and user experience within radio-based communication networks.

SUMMARY

It is a general objective to manage persistent poor radio signal propagation within a radio-based communication network.

It is a particular objective to provide such a management for improving quality of service and user experience.

These and other objectives are met by embodiments as defined herein.

An aspect of the embodiments relates to a method for managing persistent poor radio signal propagation within a radio-based communication network. The method comprises identifying a user equipment based on an estimated position of the user equipment within a cell served by a radio base station in the radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The method also comprises generating a notice informing the user equipment or a user of the user equipment of the

persistent poor radio signal propagation. The method further comprises transmitting the notice to the user equipment.

Another aspect of the embodiments relates to a device for managing persistent poor radio signal propagation within a radio-based communication network. The device is configured to identify a user equipment based on an estimated position of the user equipment within a cell served by a radio base station in the radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The device is also configured to generate a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

A further aspect of the embodiments defines a device for managing persistent poor radio signal propagation within a radio-based communication network. The device comprises a user equipment identifier for identifying a user equipment based on an estimated position of the user equipment within a cell served by a radio base station in a radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The device also comprises a notice generator for generating a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

Yet another aspect of the embodiments defines a computer program comprises instructions, which when executed by a processor, cause the processor to identify a user equipment based on an estimated position of a user equipment within a cell served by a radio base station in a radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The processor is also caused to generate a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

A related aspect of the embodiments defines a carrier comprising a computer program according to above. The carrier is one of an electronic signal, an optical signal, an electromagnetic signal, a magnetic signal, an electric signal, a radio signal, a microwave signal, or a computer-readable storage medium.

The present embodiments inform end users or their user equipment of persistent signal quality problems in advance, thereby allowing the end user or user equipment to take actions before any

problems due to the persistent poor signal quality occur. As a consequence, the user experience will improve.

Embodiments can also complement or even replace existing handover-based procedures, with the advantage of significantly reducing battery consumption of user equipment by relaxing the need to monitor signal strength not only in the current cell by also in neighboring cells.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

Fig. 1 is a flow chart of a method for managing persistent poor radio signal propagation according to an embodiment;

Fig. 2 is a flow chart of an additional, optional step of the method in Fig. 1 according to an embodiment;

Fig. 3 is a flow chart of an additional, optional step of the method in Fig. 1 according to an embodiment;

Fig. 4 is a flow chart of additional, optional steps of the method in Fig. 1 according to an embodiment;

Fig. 5 is a flow chart illustrating an embodiment of updating propagation information in Fig. 4;

Fig. 6 is a flow chart illustrating another embodiment of updating propagation information in Fig. 4;

Fig. 7 schematically illustrates a portion of a radio-based communication network;

Fig. 8 schematically illustrates a portion of a radio-based communication network;

Fig. 9 is signal diagram illustrating signaling conducted between entities involved in a method for managing persistent poor radio signal propagation according to an embodiment;

Fig. 10 is a signal diagram illustrating internal signaling within a distributed implementation of a device for managing persistent poor radio signal propagation according to an embodiment;

Fig. 11 is a schematic block diagram of a device for managing persistent poor radio signal propagation according to an embodiment;

Fig. 12 is a schematic block diagram of a device for managing persistent poor radio signal propagation according to another embodiment;

Fig. 13 is a schematic block diagram of a device for managing persistent poor radio signal propagation according to another embodiment;

Fig. 14 is a schematic block diagram of a cloud-based implementation of a device for managing persistent poor radio signal propagation according to an embodiment; and

Fig. 15 is a schematic block diagram of a computer program based implementation of a device for managing persistent poor radio signal propagation.

DETAILED DESCRIPTION

Throughout the drawings, the same reference numbers are used for similar or corresponding elements.

The present embodiments generally relate to quality of service improvement in radio-based communication networks. In particular, the present embodiments relate to quality of service improvement by management of persistent poor radio signal propagation and poor radio coverage in radio-based communication networks.

Briefly, embodiments as disclosed herein generate propagation information based on collected or received quality data and use such propagation information in order to define one or more geographical areas within a cell in the radio-based communication network that experience(s) persistent poor radio signal propagation and thereby persistent poor radio coverage.

There may be various causes of such geographical areas with persistent poor radio signal propagation. Non-limiting, but illustrative, examples include static obstacles, such as buildings or tunnels; landscape obstacles, such as hills or mountains; radio base station problems, such as due to update or maintenance of the radio base station or communication and/or processing circuitry therein or failure or problems with the radio base station or the communication and/or processing circuitry therein.

A user equipment entering such a geographical area will consequently experience a persistent poor radio signal propagation from the radio base station, i.e. poor downlink quality, and/or to the radio base station, i.e. poor uplink quality. As a consequence, the quality of service will be reduced within the relevant geographical area.

A traditional approach to handle such poor radio coverage has been to perform a handover procedure in which the user equipment is switched to a neighboring cell in the radio-based communication network. However, such a handover procedure presumes that the signal quality from the neighboring cell and the radio base station serving the neighboring cell is sufficient high also within the particular geographical area in the current cell. This is not always the case. Furthermore, traditional handover procedures are marred by shortcomings as described above in the background section.

The present embodiments thereby provide an alternative or a complement to handle persistent poor radio signal propagation situations within a radio-based communication network in order to improve the quality of service for the end users.

Fig. 1 is a flow chart illustrating a method for managing persistent poor radio signal propagation within a radio-based communication network. The method comprises identifying, in step S1, a user equipment based on an estimated position of the user equipment (UE) within a cell served by a radio base station in the radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The method also comprises generating a notice in step S2. This notice informs the user equipment or a user of the user equipment of the persistent poor radio signal propagation. The method further comprise transmitting the notice to the user equipment in step S3.

Thus, a user equipment having a risk of experiencing poor quality of service in terms of poor radio signal propagation or poor radio coverage is identified in step S1. This identification is performed based on an estimated position of the user equipment within the cell, or more generally within the radio-based network, and the propagation information. This propagation information defines a geographical area within the cell that has or experiences persistent poor radio signal propagation, i.e. persistent poor radio coverage. The estimated position of the user equipment is thereby used together with the propagation information in order to identify or detect whether the user equipment is already present within the geographical area experiencing persistent poor radio signal propagation and defined by the

propagation information or whether the user equipment is likely to enter the geographical area, i.e. is currently present close to the border of the geographical area.

Persistent poor radio signal propagation or persistent poor radio coverage as used herein implies that the poor radio signal propagation and thereby the poor radio coverage is persistent and thereby present during an extended period of time. There may be temporary fluctuations in radio signal propagation within a cell such as due to local interference from other user equipment, etc. Such temporary fluctuations are transient and thereby non-persistent. The persistent poor radio signal propagation implies that the geographical area defined by the propagation information experiences poor radio signal propagation for at least an extended period of time such as at least several hours, several days or longer, or even permanently. Examples of persistent but non-permanent causes of poor radio signal propagation could be update or maintenance of the radio base station or of the communication and/or processing circuitry therein, problems or failure of the radio base station of the communication and/or processing circuitry therein. Examples of persistent and permanent causes of poor radio signal propagation could be presence of static obstacles or landscape obstacles within the cell.

The radio base station problem may result in that it cannot provide sufficient radio coverage within a portion of its served cell, such as within one sector of the cell, although normal radio coverage and radio signal propagation is provided in the remaining part of the cell. Physical obstacles, either natural or man-made, could obstruct or block the radio signal propagation from and to the radio base station so that a part of the cell experiences poor radio signal propagation or “radio shadow” although normal radio coverage is provided in the remaining part of the cells. Fig. 7 schematically illustrates such a situation. The figure illustrates a portion of a radio-based communication network 1 with a radio base station 2 and its served cell 3. In this illustrative example a landscape obstacle 6 is present in the cell 3 resulting in a geographical area 4 within the cell 3 having or experiencing persistent poor radio signal propagation and thereby persistent poor radio coverage. The figure also shows a user equipment 5 moving towards the geographical area 4. The method as described above and illustrated in the flow chart of Fig. 1 can be used to identify the user equipment and generate the notice that informs the user equipment 5 or the user thereof of the persistent poor radio signal propagation.

The propagation information is, which will be further described herein, preferably generated based on quality data and/or feedback data collected from user equipment previously present within the cell, quality data provided by the radio base station itself and/or from neighboring radio base stations, and/or

manually input quality data. This type of input data is then processed in a statistical method in order to provide information of persistent radio signal propagation situation throughout the cell. In particular, the input data is used to identify any geographical area within the cell that is reported or measured to experience persistent poor radio signal propagation.

The propagation information, sometimes referred to as coverage information, is preferably a type of statistical information. This means that the propagation information is generated and updated as described herein based on quality data and/or feedback data from multiple sources, such as multiple user equipment and/or radio base stations. The propagation information is thereby obtained by statistically processing this quality data and/or feedback data as is further described herein. The statistical processing could range from an averaging of signal strength or signal propagation data recorded or measured for substantially the same position within the cell. Also weighted combinations of such signal strength or signal propagation data could be used with different weights depending on, for instance, the time of signal strength or propagation measurement or the source of the quality data. The averaged or weighted data could furthermore be tagged with a reliability value that could indicate, for a given position within the cell, how reliable the radio signal propagation data associated with that position is. The reliability value of radio signal propagation data could depend on how many input quality data sources that have been used to derive the radio signal propagation data and/or how recent the last quality data was reported for the particular position. Also more complex variants of statistical processing is possible as is further described herein.

The notice generated in step S2 could be in the form of a notice comprising informative data for the user of the user equipment. The notice could then, for instance, be in the form of a push notification, short messaging service (SMS) notice or a multimedia messaging service (MMS) notice comprising information of the persistent poor radio signal propagation. Thus, the notice could comprise information telling the user that he/she is currently entering a geographical area within the cell that experiences persistent poor radio signal propagation, i.e. a geographical area with reduced or limited quality of service. The notice could, as an example, inform the user that the radio quality will be reduced or low for an estimated period of time, such as X min, wherein X is estimated based on the estimated position of the user equipment and information of the traveling direction and speed of the user equipment. The user can then take any appropriate action, such as ending a current call, pausing streaming of a video clip or movie, etc. depending on the particular service or application the user is using once he/she receives the notice.

In an embodiment, step S2 of Fig. 1 comprises generating the notice comprising an instruction triggering the user equipment to take an action to compensate for the persistent poor radio signal propagation. Thus, in this embodiment the notice comprises an instruction triggering or causing the user equipment to combat or compensate for the persistent poor radio signal propagation. This means that the user equipment can take a compensating action without notifying the user. As a consequence, the notice preferably triggers the user equipment to automatically, i.e. without user-intervention, take the compensating action. Although it is preferred to include an instruction in the notice that automatically cause the user equipment to take an appropriate action without any user intervention, such an instruction could be complemented with the previously described information. In such a case, the user equipment will take actions and the user is informed of the persistent poor radio signal propagation and/or of the action that the user equipment is taking.

Fig. 2 is a flow chart illustrating an additional, optional step of the method shown in Fig. 1. The method continues from step S1 in Fig. 1. A next step S10 comprises selecting the instruction from a set of multiple instructions defining a respective action to be taken by the user equipment to compensate for the persistent poor radio signal propagation. The method then continues to step S2 in Fig. 1, where the notice is generated and comprises the instruction selected in step S10.

In this embodiment, a set of multiple instructions that could be used in order to compensate for persistent poor radio signal propagation is available. Accordingly, the most appropriate instruction for the particular user equipment can then be selected from this set when generating the notice.

The selection of instruction in step S10 and from the set can be performed based on various criteria. For instance, the selection could be performed at least partly based on the application or service the user is currently using on his/her user equipment. Thus, a particular instruction is selected if the user is involved in a call, whereas another particular instruction might be more appropriate if the user is currently receiving and watching a video stream.

Another criterion that can be used in the selection is information of the traveling direction and/or speed of the user equipment. This type of information could be used in order to estimate the period of time the user equipment will be present within the geographical area experiencing the persistent poor radio signal propagation. For instance, if the user equipment will quickly pass through the geographical area or merely a border portion thereof then a first instruction might be most appropriate whereas another

instruction is more suited if the user equipment will spend a comparatively longer period of time in the geographical area.

In an embodiment, user equipment provides feedback information of how well a particular instruction helped the user equipment when present in the geographical area. In such a case, such feedback information could be used in the selection. For instance, if a user equipment reports that the quality of service was significantly reduced even when receiving a notice with a particular instruction as generated in step S2, then such an instruction is preferably not selected for a new user equipment entering the geographical area. However, if a user equipment reports that the quality of service was significantly improved when taking an action triggered by a received instruction, then such an instruction is advantageously selected for the new user equipment.

Further criteria include current time of day and information of application or service patterns of users. Such information could be used in order to estimate the number of expected users within the geographical area and the type of services or applications such users are expected to use. For instance, the traffic through the cell could be high at the morning and evening when several users pass through the cell when going to and from their work. At other times of the day the number of users within the cell is expected to be lower. The type of instruction selected in step S10 could thereby be based on the current time of day as a basis of the most appropriate instruction given the average or expected number of users that may interfere with or compete for the limited radio resources with the current user.

Also information about the user equipment and the user, such as what kind of subscription the user has, could be used in the selection of instruction in step S10. For instance, depending on the capabilities of the user equipment then a particular instruction might be more appropriate or indeed cannot be used by the user equipment. The subscription of the user could also impose limitations in terms of what type of instructions that could be used by the user equipment.

The selection performed in step S10 could be performed based on any single criterion, such as mentioned above, or based on at least two such criteria. Thus, any combination of at least one criterion, such as what kind of application the user is using and feedback information from previous user equipment, could be employed in order to select the most appropriate instruction form the set for the current situation and user.

There are several different instructions that could be used to compensate for the persistent poor radio signal propagation and thereby select among in step S10. Non-limiting, but illustrative, examples of such instructions are presented below.

The instruction could trigger the user equipment to pre-cache data received in an ongoing communication session in a buffer of the user equipment. Thus, the user equipment is currently involved in a communication session involving reception of data packets carrying data, such as multimedia data. The communication session could, as an example, be a streaming session in which the user equipment receives a video stream and/or an audio stream. Another example could be a download session, in which the user equipment is downloading data, such as multimedia data, for instance web pages, images, etc. The instruction then triggers the user equipment to pre-cache data received in the communication session in a buffer of the user equipment. Such pre-caching reduces the risk of depleting the buffer if the persistent poor radio signal propagation in the geographical area causes a reduced bitrate and/or an increased loss of data packets. Thus, the pre-caching of data implies that the user equipment has sufficient amount of data in the buffer to handle such a reduced bitrate and/or data packet loss that otherwise would result in a stop of playing out the video and/or audio or a stop in displaying the web page or images.

The pre-caching instruction could define that the user equipment should pre-cache at least a minimum number of data packets or a minimum number of bits or bytes of data. Alternatively, the instruction could cause a change in a buffer threshold affecting the amount of buffer that is temporarily stored in the buffer prior to play out. Such a threshold change would then imply that the user equipment increases the amount of data that is kept in the buffer.

Another type of instruction could trigger the user equipment to switch to another radio-based communication network. In this case, overlapping radio-based communication networks are present in the geographical area or at least a portion thereof. As an example, the instruction could trigger the user equipment to switch from the current mobile or cellular radio-based communication network to a wireless local area network (WLAN), such as a WiFi network.

A further example is an instruction triggering the user equipment to skip a handover from the cell to a micro or pico cell. This instruction thereby stops the user equipment from performing a handover to the micro or pico cell. A typical situation could otherwise be that the user equipment is handed over from the current cell to a micro or pico cell and then shortly thereafter handed over back to the current cell or

to a neighboring cell. However, the period of time during which the user equipment is served by the micro or pico cell might be very short before it is handed over to the neighboring cell or back to the current cell. In such a case, it might be more appropriate to skip the handover from the current cell to the micro or pico cell to thereby, at somewhat later point in time, hand over the user equipment directly from the current cell to the neighboring cell. For instance, the user equipment might be running a low bandwidth application when the signal strength in the current cell A is deteriorating. The next cell the user equipment can switch to is a micro cell B, which means that the user equipment needs to switch to another cell C soon if the user equipment is handed over from cell A to cell B. In this case, it may be better for the user equipment to stay served by the current cell A, bypass, i.e. skip, cell B, and then handover directly to cell C.

The above-described instruction is in particular suitable if the user equipment is currently running an over-the-top application (OTT) involving data transfer or during an ongoing call.

Further examples of suitable instructions involve an instruction triggering the user equipment to reconfigure radio communication circuitry of the user equipment. Such a reconfiguration of the radio communication circuitry of the user equipment could compensate for the present or coming persistent poor radio signal propagation in the geographical area. Examples of reconfigurations include tuning the radio communication circuitry parameters involving or defining, for instance, transmit power, frequency bands, allocation of antennas to a different set of frequencies, modifying communication protocol timeouts, etc.

Another example is an instruction triggering the user equipment to temporarily turn off radio communication circuitry of the user equipment. In this case, the user equipment is triggered to temporarily turn off its radio communication circuitry. This approach may be advantageous if the radio signal propagation is so poor that the user equipment hardly can be involved in any communication session or application with acceptable quality of service. Turning off the radio communication circuitry furthermore saves battery power of the user equipment since the battery is quickly drained in very poor radio coverage areas when the radio communication circuitry continuously tries to access the radio-based communication network.

If the user equipment is involved in a streaming session then an instruction could trigger the user equipment to switch streaming quality level during an ongoing streaming session. For instance, the user equipment could switch to a lower bitrate for the streamed video and/or audio content. The

reduction in bitrate lowers the quality level but may enable streaming of the video and/or audio content in a situation with persistent poor radio signal propagation. Such a switch of streaming quality is generally performed at a back-end server providing the streaming service to the user equipment. Accordingly, the user equipment could be triggered to send a message or notice to the back-end server to request a reduction in the streaming quality such as by lowering the bitrate.

In another example, the user equipment is involved in an application or service provided by a back-end server. In this case, the instruction could trigger the user equipment to prolong a session timeout or reset a session timeout timer for the application or service provided by the back-end server. Generally, if the user equipment does not respond to the back-end server within a defined period of time corresponding to the session timeout timer then the back-end server typically ends the application or service session with the user equipment. If the timer is reset or the session timeout is prolonged, the user equipment will have a longer period of time to successfully respond to the back-end server. The instruction could trigger the user equipment to send a message or notice to the back-end server to request reset of the timer or prolong of the session timeout.

The instruction selected in step S10 in Fig. 2 is preferably selected from a group consisting of the above-mentioned illustrative examples of instructions or from a group consisting a subset of these instructions.

The selection of the instruction in step S10 may comprise selecting more than one instruction from the set of multiple instructions. Thus, the notice generated in step S2 may comprise more than one instruction to thereby trigger different actions in the user equipment to compensate for the persistent poor radio signal propagation.

The at least one instruction included in the notice to be sent to the user equipment could be associated with a time period or time-to-live value defining the period of time during which the user equipment is to apply the action defined by the instruction. Accordingly, once the time period has expired the user equipment could resume its previous operation and settings, such as using a previous buffer level, switch back to the previous radio-based communication network, reconfigure its radio communication circuitry, turn on its radio communication circuitry, increase streamlining quality level, or reduce the session timeout timer, etc. Alternatively, a new notice is generated and transmitted to the user equipment once the user equipment has left or is about to leave the geographical area defined by the

propagation information. This new notice could then trigger the user equipment to resume its previous operation and settings.

Fig. 3 is a flow chart illustrating an additional, optional step of the method shown in Fig. 1. The method continues form step S3 in Fig. 1. A next step S20 comprises updating the set of multiple instructions based on feedback data from the user equipment, wherein the feedback data represents an outcome of taking the action to compensate for the persistent poor radio signal propagation defined by the instruction.

In this embodiment, the user equipment provides feedback information representing the outcome of taking the action defined by the instruction included in the notice generated in step S2. The outcome could be a simple two-way value either specifying desired or acceptable outcome or specifying undesired or unacceptable outcome. In the former case, the instruction had the desired action and thereby increased the quality of service of the user by compensating for the persistent poor radio signal propagation. In the latter case, the instruction selected for the user equipment did not result in the desired outcome and thereby quality of service for the user. The outcome could thereby define whether the selected instruction was suitable or unsuitable given the situation experienced by the user equipment when entering the geographical area with persistent poor radio signal propagation.

In other embodiments, the feedback information could provide more detailed information with regard to the outcome of taking the action defined by the instruction. Such detailed information may include measured quality data, such as data throughput, bitrate, packet loss, etc. depending on the particular application or session the user equipment is involved in when taking the action.

The update performed in step S20 could thereby remove instructions that did not result in the desired outcome when applied on user equipment or modify such instructions to try to increase the quality of service for the user if the modified instruction is applied. Correspondingly, a successful instruction as indicated by the feedback data should preferably be selected for another user equipment in a similar situation as the user equipment providing the feedback data. The chances of obtaining the desired result in terms of quality of service are thereby higher by selecting an instruction that previously has been successfully applied as indicated by feedback data.

In an embodiment, step S1 of Fig. 1 comprises determining whether the estimated position of the user equipment is within the geographical area defined by the propagation information. In this embodiment, the notice is generated in step S2 once the user equipment has entered the geographical area.

In another embodiment, see Fig. 8, step S1 of Fig. 1 comprises determining whether the estimated position of the user equipment 5 is within a border area 7 bordering to the geographical area 4 defined by the propagation information. Thus, in this embodiment the notice is generated in step S2 when the user equipment 5 is close to but has not yet entered the geographical area 4. The border area 7 thereby corresponds to an area around and bordering to the geographical area 4 at which the notice is generated. This allows sufficient time to generate the notice and transmit it to the user equipment 5, where the instruction preferably comprised therein is applied to take an action to compensate for the persistent poor radio signal propagation in the geographical area 4, before the user equipment 5 enters the geographical area 4. Hence, the compensating action has already been taken prior to experiencing the persistent poor radio signal propagation.

In an embodiment, step S1 of Fig. 1 comprises determining whether the user equipment will enter the geographical area defined by the propagation information based on the estimated position of the user equipment and based on an estimated speed and direction of travel of the user equipment. Hence, in this embodiment not only the estimated position of the user equipment is used to identify the user equipment and determine whether the user equipment will enter the geographical area. In clear contrast, also the estimated speed and direction of travel of the user equipment is preferably used. This is schematically illustrated in Fig. 7, in which the arrow indicates the direction of travel of the user equipment 5. This means that it is possible to identify those user equipment 5 that are likely to enter the geographical area 4 even if the current estimated position of the user equipment 5 is outside of the geographical area 4.

The estimated direction of travel together with the estimated position enables determination whether the user equipment 5 will enter the geographical area. The estimated speed together with the estimated position enables determining an estimated point in time when the user equipment 5 will enter the geographical area 4. This in turn enables coordinating generation and transmission of the notice so that the user equipment 5 receives the notice and can apply the instruction prior to entering the geographical area 4. In particular, the generation and transmission of the notice could be coordinated so that the user equipment takes the action defined by the instruction in the notice as close as possible prior to entering the geographical area 4. Thus, it is generally preferred to take the compensating action

immediately prior to entering the geographical area 4 in clear contrast to once the user equipment 5 has already entered the geographical area 4.

Thus, in a particular embodiment step S1 comprises determining whether the user equipment 5 will enter the geographical area 4 defined by the propagation information based on the estimated position of the user equipment 5 and based on an estimated direction of travel of the user equipment 5.

In another particular embodiment, the method further comprises coordinating generation of the notice and/or transmission of the notice based on the estimated position of the user equipment 5 and based on an estimated speed of the user equipment 5.

Information of the position of the user equipment can be received from the user equipment itself. For instance, the user equipment could periodically or upon request return information of its current position within the cell. This current position may in turn be determined by the user equipment using techniques well known in the art, such as using a global positioning system (GPS) receiver in the user equipment or techniques for position determination in cellular networks. The user equipment can then provide this position information. Alternatively, the radio-based communication network can estimate the position of the user equipment using a network-based position location, such as a fingerprinting method, received signal strength (RSS) method, angle of arrival (AOA) method, time of arrival (TOA) method or time difference of arrival (TDOA) method as illustrative examples. The estimated position could then be provided from a radio base station of the radio-based communication network.

The direction of travel and/or the speed of the user equipment can be received from the user equipment or be estimated from multiple previous positions of the user equipment, such as based on such position information received from the user equipment and/or a radio base station. Thus, by having access to multiple past positions for a user equipment it is possible to estimate the direction of travel of the user equipment. Correspondingly, if these past positions are time-stamped, such as by recording the time at which the position was measured or estimated or the time at with the position information was received, the speed of the user equipment can be estimated.

Fig. 4 is a flow chart illustrating additional, optional steps of the method in Fig. 1. The method starts in step S30, which comprises receiving position data and quality data from multiple user equipment. The quality data then represents measured signal quality at a position within the cell represented by the

position information. The next step S31 comprises updating the propagation information by statistically processing the position data and the quality data. The method then continues to step S1.

In another embodiment, step S30 comprises receiving position data and quality data from the radio base station. The quality data then represents measured signal quality at a position within the cell represented by the position data. The next step S31 comprises updating the propagation information by statistically processing the position data and the quality data. The method then continues to step S1.

In a further embodiment, step S30 comprises receiving position data and quality data from the radio base station. The quality data then indicates a reduced signal quality due to radio base station problem affecting a position within the cell represented by the position data. The next step S31 comprises updating the propagation information by statistically processing the position data and the quality data. The method then continues to step S1.

The above three embodiments define variants of how to generate and update the propagation information by statistical processing feedback data in terms of quality data and position data.

In the former two embodiments, the quality data represents measured signal quality, such as in terms of experienced radio coverage, measured bandwidth, ping round-trip time, etc. This quality data can either be provided by the user equipment together with the position information defining the position at which the signal quality was measured or by the radio base station.

In the latter case, the quality data indicates a reduced signal quality due to radio base station problem. This includes, for instance, scheduled update or maintenance of the radio base station or communication and/or processing circuitry therein or failure or problems with the radio base station or the communication and/or processing circuitry therein. Regardless of the cause, the effect is a reduced signal quality affecting a position within the cell represented by the position data. This position data could, for instance, define a sector or larger area within the cell that is affected by the maintenance or failure. This type of quality and position data could be manually input by the operator of the radio base station or could be automatically generated by problem detecting circuitry within the radio base station.

The above-described embodiments may be combined. This means that quality data, such as in terms of measured signal quality, received from both user equipment and from the radio base station could be used in the update of the propagation information. Furthermore, quality data representing radio base

station problem may be combined with quality data from user equipment, with quality data from the radio base station or indeed with quality data from both user equipment and from the radio base station.

The propagation information generated and used as described herein is preferably updated over time to reflect any changes in the radio signal propagation throughout the cell served by the radio base station. For instance, the radio signal propagation situation might improve in the previously affected geographical area, such as by removing or eliminating an obstacle blocking radio signal propagation or by ending maintenance of or fixing failure of the radio base station or the radio communication and/or processing circuitry thereof.

For instance, if the poor quality of service was caused by a failure or maintenance work, then a manual step of the network operator can be taken to reset the propagation information or update the propagation information after the failure has been resolved or the maintenance is over.

Another embodiment would be to associate the propagation information with a time-to-live (TTL) value or period. In such a case, the propagation information is only valid as long as the TTL period has not yet expired. After the end of the TTL period the propagation information is regarded as invalid, thereby triggering a new period of collecting quality data from various sources, such as user equipment and/or radio base stations in order to generate new or updated propagation information.

It is generally preferred if the user equipment provides quality data and feedback data in order to maintain the propagation information as update and correct as possible over time. This means that even if a user equipment selects to not apply a received instruction it still preferably sends quality data and/or feedback data. In this case, the feedback data will represent the outcome of not taking any action as defined by the instruction.

It is also possible to refrain from transmitting any notice with instruction to some user equipment identified to be present within or likely to enter the geographical area. There could be various reasons for this. For instance, a user equipment might be present within the geographical area for a very limited period of time, which is so short that the quality of service for the user will hardly be affected even though the radio signal propagation is poor within the geographical area.

The statistical processing of the received quality data and position data can be performed according to various embodiments. In an illustrative embodiment, average radio signal propagation could be determined throughout the cell based on the quality data and the position information. This means that such average radio signal propagation is determined for various positions within the cell to thereby define the geographical area experiencing the persistent poor radio signal propagation. More complex statistical processing than simple averaging are possible including, for instance, using a weighted combination of quality data wherein different weights could be used for more recent reported quality data as compared to past reported quality data and/or using different weights depending on the source of the quality data, i.e. user equipment vs. radio base station.

Fig. 5 is a flow chart illustrating an embodiment of updating the propagation information in Fig. 4. The method continues from step S30 in Fig. 4. A next step S40 comprises finding patterns of poor signal quality based on the quality data. The following step S41 comprises identifying locations within the cell corresponding to the patterns of poor signal quality based on the position information. The geographical data is then defined in step S42 based on the patterns of poor signal quality and the locations.

In this embodiment, the statistical processing comprises finding patterns of poor signal quality and thereby poor radio coverage within the cell and identifying those locations or the portions of the cell corresponding to these patterns.

An advantage of the statistical processing of the embodiments based on quality data from multiple sources, such as multiple user equipment and/or radio base stations, is that it enables finding patterns of persistent poor signal quality as compared to transient fluctuations in signal quality. The propagation information could thereby be seen as map over persistent radio coverage and radio signal propagation throughout the cell and where the geographical area is identified as a sink with significantly reduced radio signal propagation and coverage as compared to other parts of the cell.

Fig. 6 is a flow chart illustrating another embodiment of updating the propagation information. The method continues from step S30 in Fig. 4. A next step S50 comprises performing root cause analysis (RCA) based on the position data and the quality data to identify multiple root causes of poor signal quality. A next step S51 determines an instruction defining a respective action to be taken by the user equipment to compensate for the persistent poor radio signal propagation of a root cause. This step S51 is preferably performed for each root cause of the multiple root causes, which is schematically illustrated by the line L1. The method then continues to step S1 in Fig. 1 or to step S31 in Fig. 4.

Generally, RCA is a method of problem solving used for identifying the root causes of faults or problems. RCA is applied to methodically identify and correct the root causes of events, rather than to simply address the symptomatic result. Focusing correction on root causes has the goal of entirely preventing problem recurrence. This means that by applying RCA on the received quality data and the position data multiple root causes are identified. A most suitable instruction is then preferably determined for each such root cause.

An example of applying RCA could be based on rule engine. Essentially a database of rules are defined by network experts, such as if problem A then root cause A. If the user equipment experiences a particular problem, the problem can be fed into the rule engine in order to output the associated root cause. In another example, RCA can be built on reasoning engine. In this case, there is generally no predefined rule. When a user equipment reports a problem, firstly a manual step is involved to identify the root cause. However, at a later point in time if another user equipment reports a similar problem, the reasoning engine will identify the relevant root cause that best matches the problem.

The problem experienced by the user equipment could be determined based on the quality data reported from user equipment and optionally also from radio base stations. Optionally also metadata provided together or in connection with the quality data could be used in the RCA method and problem identification. Non-limiting examples of such metadata include user equipment data, such as model or serial number, network identifier, information of current communication service or application, etc.

The transmission of the notice to the user equipment in step S3 of Fig. 1 preferably comprises transmitting the notice to the user equipment preferably prior to the user equipment entering the geographical area defined by the propagation information.

In another embodiment, this step S3 comprises transmitting the notice to the user equipment when the user equipment is within the geographical area defined by the propagation information.

In this latter embodiment, the transmission is preferably coordinated so that once the estimated position of the user equipment indicates that the user equipment is within geographical area defined by the propagation information the notice is generated and transmitted to the user equipment.

In the former embodiment, the transmission of the notice could be coordinated to take place once the user equipment is within the border area, see Fig. 8, bordering the geographical area. Alternatively, or in addition, the transmission of the notice could be coordinated based on the estimated position of the user equipment and based on the estimated speed of the user equipment and optionally based on the estimated direction of travel of the user equipment as previously described herein.

Fig. 9 is a signal diagram illustrating signaling conducted between entities involved in a method for managing persistent poor radio signal propagation according to an embodiment. The upper part of the signal diagram illustrates collecting and statistically processing quality data in order to update the propagation information and define instructions.

Thus, user equipment (UE) and radio base stations (RBS) report quality data and position data to a device for managing persistent poor radio signal propagation. This report in particular takes place at positions at which the user equipment or radio base station detects poor signal quality. However, such quality and position data reports could also take place at positions with sufficient signal quality. The device statistically processes the received quality and position data to thereby update the propagation information and the geographical area defined by the propagation information. The device may optionally also apply RCA on the quality and position data to thereby generate a set of multiple instructions.

In the illustrative example, a user equipment reports its estimated position. In other embodiments, this estimated position may come from other sources, such as the radio base station. The propagation information is used together with the estimated position to determine whether the user equipment is likely to enter the geographical area experiencing persistent poor radio signal propagation. The device preferably also selects a suitable instruction from the set of multiple instructions. A notice preferably comprising the selected instruction is generated and transmitted to the user equipment. There the user equipment processes the instruction triggering an action that compensates for the persistent poor radio signal propagation.

In a preferred embodiment, the user equipment generates and returns feedback data defining the outcome of the taken action to the device. The device then preferably updates the propagation information and in particular the set of instructions and the selection of instructions based on the feedback data.

In Fig. 9, the device has been illustrated as a single entity or node. In an alternative embodiment, the functions of the device could be distributed among multiple nodes represented by a monitor node, a processing node and an instruction node in Fig. 10. In this distributed implementation example, the monitor node receives the quality and position data, such as from user equipment and radio base stations. The monitor node either automatically forwards the quality and position data to the processing node or sends the data thereto upon reception of a data request from the processing node. The processing node statistically processes the quality and position data in order to update the propagation information and the geographical area. In this embodiment, the processing node also applies RCA on the quality and position data.

The processing node then transmits an instruction request to the instruction node causing the instruction node to generate a set of instructions. This generation is preferably based on the result of the RCA processing, which may be included in the instruction request. Alternatively, the RCA processing could be performed by the instruction node. In such a case, the processing node preferably provides the quality and position data to the instruction node to be used therein, such as in the RCA processing. In either case, the instruction node returns with the generated set of instructions.

In this example, the estimated position of a user equipment is received by the monitor node, which forwards status of the user equipment to the processing node. This status may include more information than only the estimated position, such as estimated speed and direction of travel. The processing node identifies the user equipment as likely to enter the geographical area, selects an appropriate instruction and generates the notice. The notice is transmitted to the user equipment.

The user equipment may then provide feedback data similar to Fig. 9 but in this case to the monitor node, which forwards it to the processing node. The processing node may then use the feedback data to update the propagation information.

Another aspect of the embodiments relates to a device for managing persistent poor radio signal propagation within a radio-based communication network. The device is configured to identify a user equipment based on an estimated position of the user equipment within a cell served by a radio base station in the radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The device is also configured to generate a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

In an embodiment, the device is configured to generate the notice comprising an instruction triggering the user equipment to take an action to compensate for the persistent poor radio signal propagation.

The device is configured, in an embodiment, to select the instruction from a set of multiple instructing defining a respective action to be taken by the user equipment to compensate for the persistent poor radio signal propagation.

In an embodiment, the device is configured to update the set of multiple instructions based on feedback data from the user equipment representing an outcome of taking the action to compensate for the persistent poor radio signal propagation defined by the instruction.

In an embodiment, the device is configured to select the instruction from a group consisting of i) an instruction triggering the user equipment to pre-cache data received in an ongoing communication session in a buffer of the user equipment, ii) an instruction trigger the user equipment to switch to another radio-based communication network, iii) an instruction triggering the user equipment to skip a handover from the cell to a micro or pico cell, iv) an instruction triggering the user equipment to reconfigure radio communication circuitry of the user equipment, v) an instruction triggering the user equipment to temporarily turn off radio communication circuitry of the user equipment, and vi) an instruction triggering the user equipment to switch streaming quality level during an ongoing streaming session.

In an embodiment, the device is configured to determine whether the estimated position of the user equipment is within the geographical area defined by the propagation information. In another embodiment, the device is configured to determine whether the estimated position of the user equipment is within a border area bordering to the geographical area defined by the propagation information.

In an embodiment, the device is configured to determine whether the user equipment will enter the geographical area defined by the propagation information based on the estimated position of the user equipment and based on an estimated speed and direction of travel of the user equipment.

In a particular embodiment, the device is configured to determine whether the user equipment will enter the geographical area defined by the propagation information based on the estimated position of the

user equipment and based on an estimated direction of travel of the user equipment. In an alternative or additional particular embodiment, the device is configured to coordinate generation and/or transmission of the notice based on the estimated position of the user equipment and based on an estimated speed of the user equipment.

In an embodiment, the device is configured to update the propagation information by statistically processing position data and quality data received from multiple user equipment. The quality data represents measured signal quality at a position within the cell represented by the position data.

In an embodiment, the device is, alternatively or in addition, configured to update the propagation information by statistically processing position data and quality data received from the radio base station. The quality data represents measured signal quality at a position within the cell defined by the position data.

In an embodiment, the device is, alternatively or in addition, configured to update the propagation information by statistically processing input position data and quality data. The quality data indicates a reduced signal quality due to radio base station problem affecting a position within the cell represented by the position data.

In an embodiment, the device is configured to find patterns of poor signal quality based on the quality data. The device is also configured to identify locations within the cell corresponding to the patterns of poor signal quality based on the position data. The device is further configured to define the geographical area based on the patterns of poor signal quality and the locations.

In an embodiment, the device is configured to perform root cause analysis based on the position data and the quality data to identify multiple root causes of poor signal quality. The device is also configured to determine, for each root cause of the multiple root causes, an instruction defining a respective action to be taken by the user equipment to compensate for the persistent poor radio signal propagation of the root cause.

In an embodiment, the device is configured to transmit the notice to the user equipment. In a particular embodiment, the device is configured to transmit the notice to the user equipment prior to the user equipment enters the geographical area defined by the propagation information. In another particular

embodiment, the device is configured to transmit the notice to the user equipment when the user equipment is within the geographical area defined by the propagation information.

It will be appreciated that the methods and devices described herein can be combined and re-arranged in a variety of ways.

For example, embodiments may be implemented in hardware, or in software for execution by suitable processing circuitry, or a combination thereof.

The steps, functions, procedures, modules and/or blocks described herein may be implemented in hardware using any conventional technology, such as discrete circuit or integrated circuit technology, including both general-purpose electronic circuitry and application-specific circuitry.

Particular examples include one or more suitably configured digital signal processors and other known electronic circuits, e.g. discrete logic gates interconnected to perform a specialized function, or Application Specific Integrated Circuits (ASICs).

Fig. 11 illustrates a particular hardware implementation of the device 100 according to an embodiment. The device 100 comprises a user equipment identifier 101 configured to identify the user equipment based on the estimated position and based on the propagation information. The device 100 also comprises as notice generator 102 configured to generate the notice.

In an embodiment, the device 100 also comprises a receiver 103 and a transmitter 104. The receiver 103 is then configured to receive, among others, the estimated position of the user equipment, whereas the transmitter 104 is configured to transmit the notice to the user equipment.

In the figure, the receiver 103 and transmitter 104 have been illustrated as separated devices. In an alternative embodiment, they can be replaced by a common transceiver.

The receiver 103 is preferably connected to the user equipment identifier 101 in order to forward the received estimated position thereto. The user equipment identifier 101 is preferably connected to the notice generator 102 in order to provide information of the user equipment identified by the user equipment identifier 101. The notice generator 102 is preferably connected to the transmitter 104 in order to forward the generated notice for transmission by the transmitter 104.

Alternatively, at least some of the steps, functions, procedures, modules and/or blocks described herein may be implemented in software such as a computer program for execution by suitable processing circuitry such as one or more processors or processing units.

Examples of processing circuitry includes, but is not limited to, one or more microprocessors, one or more Digital Signal Processors (DSPs), one or more Central Processing Units (CPUs), video acceleration hardware, and/or any suitable programmable logic circuitry such as one or more Field Programmable Gate Arrays (FPGAs), or one or more Programmable Logic Controllers (PLCs).

It should also be understood that it may be possible to re-use the general processing capabilities of any conventional device, unit, system or arrangement in which the proposed technology is implemented. It may also be possible to re-use existing software, e.g. by reprogramming of the existing software or by adding new software components.

In a particular example, the device 110, see Fig. 12, comprises a processor 111 and a memory 112 comprising instructions executable by the processor 111. The processor 111 is operative to identify the user equipment based on the estimated position and based on the propagation information. The processor 111 is also operative to generate the notice.

In an embodiment, the device 110 also comprises, in addition to the processor 111 and the memory 112, a receiver 113 and a transmitter 114 as shown in Fig. 12.

In a particular embodiment, the processor 111 is operative, when executing the instructions stored in the memory 112, to perform the above-described operations. The processor 111 is thereby interconnected to the memory 112 to enable normal software execution.

The optional receiver 113 is then configured to receive, among others, the estimated position of the user equipment and the optional transmitter 114 is configured to transmit the generated notice to the user equipment.

Fig. 15 is a schematic block diagram illustrating an example of a device 200 comprising a processor 210, an associated memory 220 and a communication circuitry 230.

In this particular example, at least some of the steps, functions, procedures, modules and/or blocks described herein are implemented in a computer program 240, which is loaded into the memory 220 for execution by processing circuitry including one or more processors 210. The processor 210 and memory 220 are interconnected to each other to enable normal software execution. A communication circuitry 230 is also interconnected to the processor 210 and/or the memory 220 to enable input of, among others, estimated positions of user equipment and output of generated notices.

The term 'processor' should be interpreted in a general sense as any system or device capable of executing program code or computer program instructions to perform a particular processing, determining or computing task.

The processing circuitry including one or more processors is thus configured to perform, when executing the computer program, well-defined processing tasks such as those described herein.

The processing circuitry does not have to be dedicated to only execute the above-described steps, functions, procedure and/or blocks, but may also execute other tasks.

In an embodiment, the computer program 240 comprises instructions, which when executed by the processor 210, cause the processor 210 to identify a user equipment based on an estimated position of a user equipment within a cell served by a radio base station in a radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The processor is also caused to generate a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

The proposed technology also provides a carrier 250 comprising the computer program 240. The carrier 250 is one of an electronic signal, an optical signal, an electromagnetic signal, a magnetic signal, an electric signal, a radio signal, a microwave signal, or a computer-readable storage medium 250.

By way of example, the software or computer program 240 may be realized as a computer program product, which is normally carried or stored on a computer-readable medium 250, preferably non-volatile computer-readable storage medium 250. The computer-readable medium 250 may include one or more removable or non-removable memory devices including, but not limited to a Read-Only Memory (ROM), a Random Access Memory (RAM), a Compact Disc (CD), a Digital Versatile Disc

(DVD), a Blue-ray disc, a Universal Serial Bus (USB) memory, a Hard Disk Drive (HDD) storage device, a flash memory, a magnetic tape, or any other conventional memory device. The computer program 240 may thus be loaded into the operating memory 220 of a computer or equivalent processing device, represented by the device 200 in Fig. 15, for execution by the processor 210 thereof.

The flow diagram or diagrams presented herein may therefore be regarded as a computer flow diagram or diagrams, when performed by one or more processors. A corresponding device may be defined as a group of function modules, where each step performed by the processor corresponds to a function module. In this case, the function modules are implemented as a computer program running on the processor. Hence, the device may alternatively be defined as a group of function modules, where the function modules are implemented as a computer program running on at least one processor.

An example of such function modules is illustrated in Fig. 13 illustrating a schematic block diagram of a device 120 with function modules. The device 120 comprises a user equipment identifier 121 for identifying a user equipment based on an estimated position of the user equipment within a cell served by a radio base station in a radio-based communication network and based on propagation information defining a geographical area within the cell experiencing persistent poor radio signal propagation. The device 120 also comprises a notice generator 122 for generating a notice informing the user equipment or a user of the user equipment of the persistent poor radio signal propagation.

The device 120 may optionally comprise an input and output (I/O) unit 123 for inputting the estimated position and for outputting the generated notice.

A further aspect of the embodiments relates to a radio base station comprising a device for managing persistent poor radio signal propagation within a radio-based communication network, such as illustrated in any of Figs. 12 to 14. The radio base station could be any network node or entity providing communication services to user equipment within a cell, i.e. within an area in the radio-based communication network. Such radio base stations are traditionally denoted network node, base station, radio base station, NodeB, eNodeB or general communication access point in the art.

The user equipment can be any mobile or portable user equipment capable of conducting communication services with radio base stations in a radio-based communication network. The user equipment may be in the form of a mobile telephone, a smart phone, a tablet, or a laptop as illustrative but non-limiting examples.

Fig. 14 illustrates a cloud-based implementation of the device 10 for managing persistent poor radio signal propagation within a radio-based communication network. In this distributed implementation, the functions of the device 10 are distributed among different network nodes or network devices present in or connected to a wired and/or wireless communication network, represented by the could in Fig. 14. This means that the user equipment identifier 11 and the notice generator 12 of the device 10 could be implemented at different physical devices in or connected to the communication network. It is indeed possible to distribute the processing and functionality of the user identifier 11 and/or the notice generator 12 among multiple such network devices or nodes. The figure also illustrates the optional I/O unit 13 or a transceiver (TRX) 13 as illustrative examples of functionality for conducting communication with user equipment.

The embodiments described above are to be understood as a few illustrative examples of the present invention. It will be understood by those skilled in the art that various modifications, combinations and changes may be made to the embodiments without departing from the scope of the present invention. In particular, different part solutions in the different embodiments can be combined in other configurations, where technically possible. The scope of the present invention is, however, defined by the appended claims.

CLAIMS

1. A method for managing persistent poor radio signal propagation within a radio-based communication network (1), said method comprising:

identifying (S1) a user equipment (5) based on an estimated position of said user equipment (5) within a cell (3) served by a radio base station (2) in said radio-based communication network (1) and based on propagation information defining a geographical area (4) within said cell (3) experiencing persistent poor radio signal propagation;

generating (S2) a notice informing said user equipment (5) or a user of said user equipment (5) of said persistent poor radio signal propagation; and

transmitting (S3) said notice to said user equipment (5).

2. The method according to claim 1, wherein generating (S2) said notice comprises generating (S2) said notice comprising an instruction triggering said user equipment (5) to take an action to compensate for said persistent poor radio signal propagation.

3. The method according to claim 2, further comprising selecting (S10) said instruction from a set of multiple instructions defining a respective action to be taken by said user equipment (5) to compensate for said persistent poor radio signal propagation.

4. The method according to any of the claims 1 to 3, wherein identifying (S1) said user equipment (5) comprises determining whether said estimated position of said user equipment (5) is within a border area (7) bordering to said geographical area (4) defined by said propagation information.

5. The method according to any of the claims 1 to 4, wherein identifying (S1) said user equipment (5) comprises determining whether said user equipment (5) will enter said geographical area (4) defined by said propagation information based on said estimated position of said user equipment (5) and based on an estimated speed and direction of travel of said user equipment (5).

6. A device (10, 100, 110) for managing persistent poor radio signal propagation within a radio-based communication network (1), wherein

said device (10, 100, 110) is configured to identify a user equipment (5) based on an estimated position of said user equipment (5) within a cell (3) served by a radio base station (2) in said radio-based communication network (1) and based on propagation information defining a geographical area (4) within said cell (3) experiencing persistent poor radio signal propagation; and

said device (10, 100, 110) is configured to generate a notice informing said user equipment (5) or a user of said user equipment (5) of said persistent poor radio signal propagation.

7. The device according to claim 6, wherein said device (10, 100, 110) is configured to generate said notice comprising an instruction triggering said user equipment (5) to take an action to compensate for said persistent poor radio signal propagation.

8. The device according to claim 7, wherein said device (10, 100, 110) is configured to select said instruction from a set of multiple instructions defining a respective action to be taken by said user equipment (5) to compensate for said persistent poor radio signal propagation.

9. The device according to claim 8, wherein said device (10, 100, 110) is configured to update said set of multiple instructions based on feedback data from said user equipment (5) representing an outcome of taking said action to compensate for said persistent poor radio signal propagation defined by said instruction.

10. The device according to any of the claims 7 to 9, wherein said device (10, 100, 110) is configured to select said instruction from a group consisting of:

an instruction triggering said user equipment (5) to pre-cache data received in an ongoing communication session in a buffer of said user equipment (5);

an instruction triggering said user equipment (5) to switch to another radio-based communication network;

an instruction triggering said user equipment (5) to skip a handover from said cell (3) to a micro or pico cell:

an instruction triggering said user equipment (5) to reconfigure radio communication circuitry of said user equipment (5);

an instruction triggering said user equipment (5) to temporarily turn off radio communication circuitry of said user equipment (5); and

an instruction triggering said user equipment (5) to switch streaming quality level during an ongoing streaming session.

11. The device according to any of the claims 6 to 10, wherein said device (10, 100, 110) is configured to determine whether said estimated position of said user equipment (5) is within said geographical area (4) defined by said propagation information.

12. The device according to any of the claims 6 to 10, wherein said device (10, 100, 110) is configured to determine whether said estimated position of said user equipment (5) is within a border area (7) bordering to said geographical area (4) defined by said propagation information.

13. The device according to any of the claims 6 to 12, wherein said device (10, 100, 110) is configured to determine whether said user equipment (5) will enter said geographical area (4) defined by said propagation information based on said estimated position of said user equipment (5) and based on an estimated speed and direction of travel of said user equipment (5).

14. The device according to any of the claims 6 to 13, wherein said device (10, 100, 110) is configured to update said propagation information by statistically processing position data and quality data received from multiple user equipment (5), wherein said quality data represents measured signal quality at a position within said cell (3) represented by said position data.

15. The device according to any of the claims 6 to 14, wherein said device (10, 100, 110) is configured to update said propagation information by statistically processing position data and quality data received from said radio base station (2), wherein said quality data represents measured signal quality at a position within said cell (3) represented by said position data.

16. The device according to any of the claims 6 to 15, wherein said device (10, 100, 110) is configured to update said propagation information by statistically processing input position data and quality data, wherein said quality data indicates a reduced signal quality due to radio base station problem affecting a position within said cell (3) represented by said position data.

17. The device according to any of the claims 14 to 16, wherein

said device (10, 100, 110) is configured to find patterns of poor signal quality based on said quality data;

said device (10, 100, 110) is configured to identify locations within said cell (3) corresponding to said patterns of poor signal quality based on said position data; and

said device (10, 100, 110) is configured to define said geographical area (4) based on said patterns of poor signal quality and said locations.

18. The device according to any of the claims 14 to 17, wherein

said device (10, 100, 110) is configured to perform root cause analysis based on said position data and said quality data to identify multiple root causes of poor signal quality; and

said device (10, 100, 110) is configured to determine, for each root cause of said multiple root causes, an instruction defining a respective action to be taken by said user equipment (5) to compensate for said persistent poor radio signal propagation of said root cause.

19. The device according to any of the claims 6 to 18, wherein said device (10, 100, 110) is configured to transmit said notice to said user equipment (5) prior to said user equipment (5) entering said geographical area (4) defined by said propagation information.

20. The device according to any of the claims 6 to 19, further comprising:

a user equipment identifier (101) configured to identify said user equipment (5) based on said estimated position and based on said propagation information; and

a notice generator (102) configured to generate said notice.

21. The device according to any of the claims 6 to 19, further comprising:

a processor (111); and

a memory (112) comprising instructions executable by said processor (111), wherein

said processor (111) is operative to identify said user equipment (5) based on said estimated position and based on said propagation information; and

said processor (111) is operative to generate said notice.

22. A device (120) for managing persistent poor radio signal propagation within a radio-based communication network (1), said device (120) comprises:

a user equipment identifier (121) for identifying a user equipment (5) based on an estimated position of said user equipment (5) within a cell (3) served by a radio base station (2) in said radio-based communication network (1) and based on propagation information defining a geographical area (4) within said cell (3) experiencing persistent poor radio signal propagation; and

a notice generator (122) for generating a notice informing said user equipment (5) or a user of said user equipment (5) of said persistent poor radio signal propagation.

23. A radio base station (2) comprising a device (10, 100, 110, 120) according to any of the claims 6 to 22.

24. A computer program (240) comprising instructions, which when executed by a processor (210), cause said processor (210) to

identify a user equipment (5) based on an estimated position of a user equipment (5) within a cell (3) served by a radio base station (2) in a radio-based communication network (1) and based on propagation information defining a geographical area (4) within said cell (3) experiencing persistent poor radio signal propagation; and

generate a notice informing said user equipment (5) or a user of said user equipment (5) of said persistent poor radio signal propagation.

25. A carrier (250) comprising a computer program (240) according to claim 24, wherein said carrier (250) is one of an electronic signal, an optical signal, an electromagnetic signal, a magnetic signal, an electric signal, a radio signal, a microwave signal, or a computer-readable storage medium.

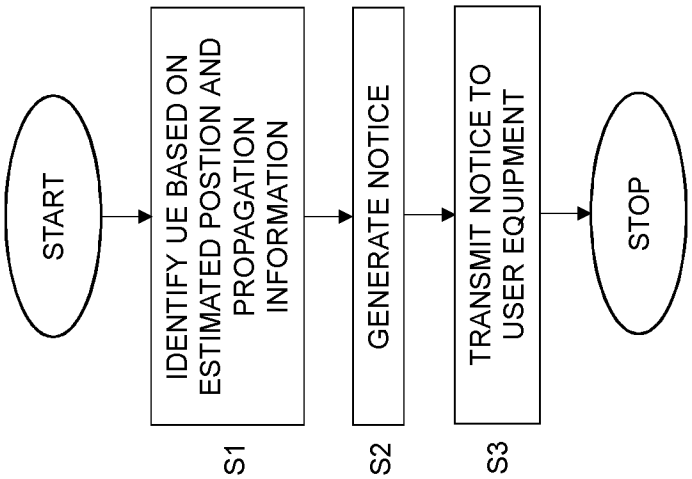

Fig. 1

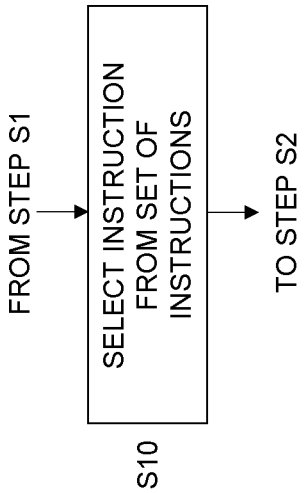

Fig. 2

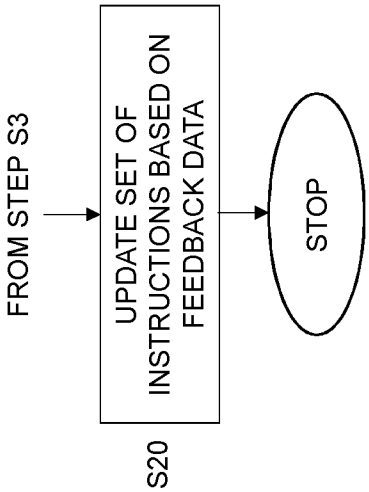

Fig. 3

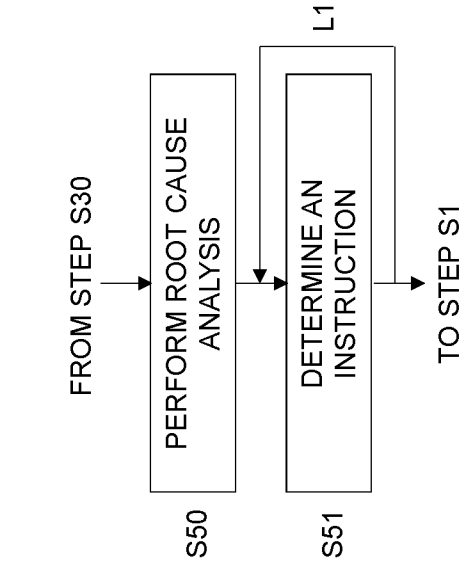

Fig. 6

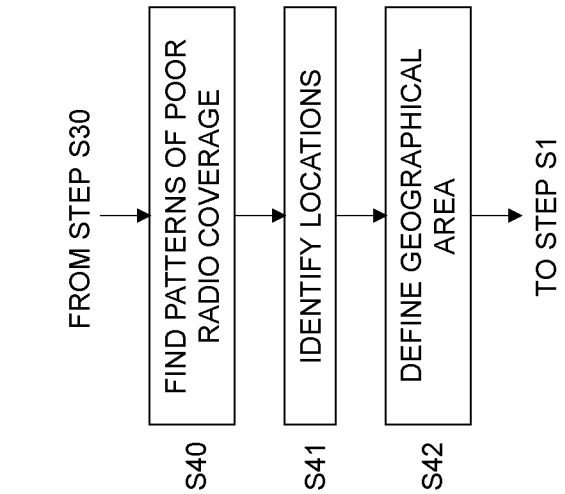

Fig. 5

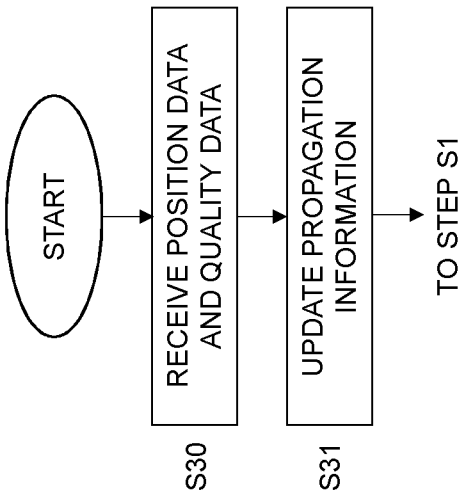

Fig. 4

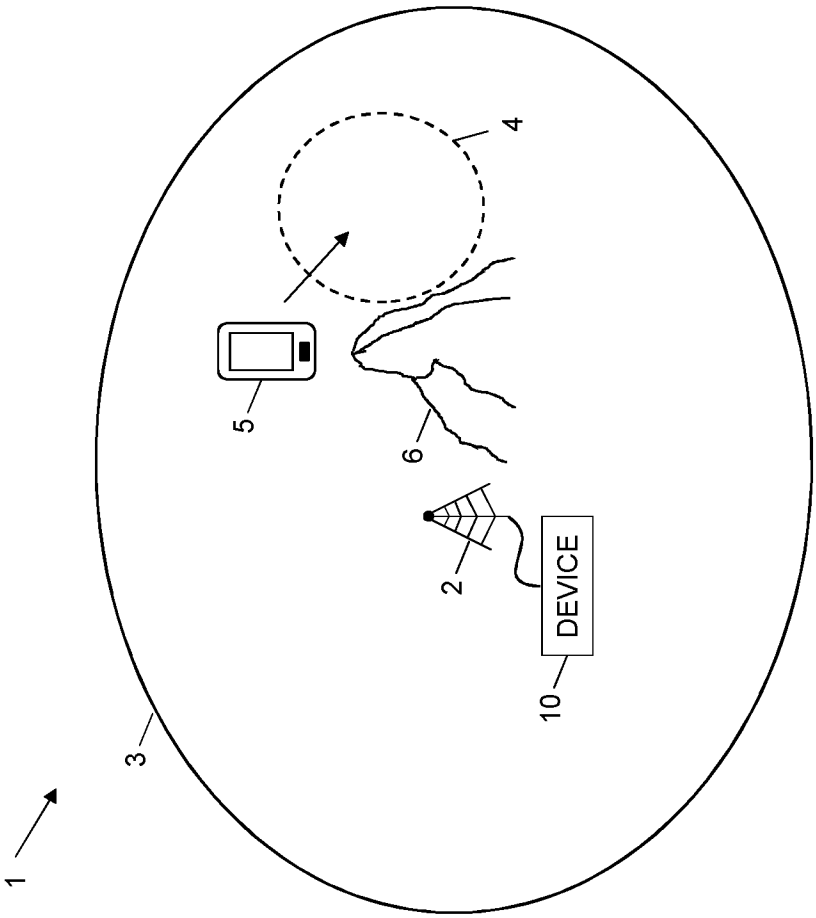

Fig. 7

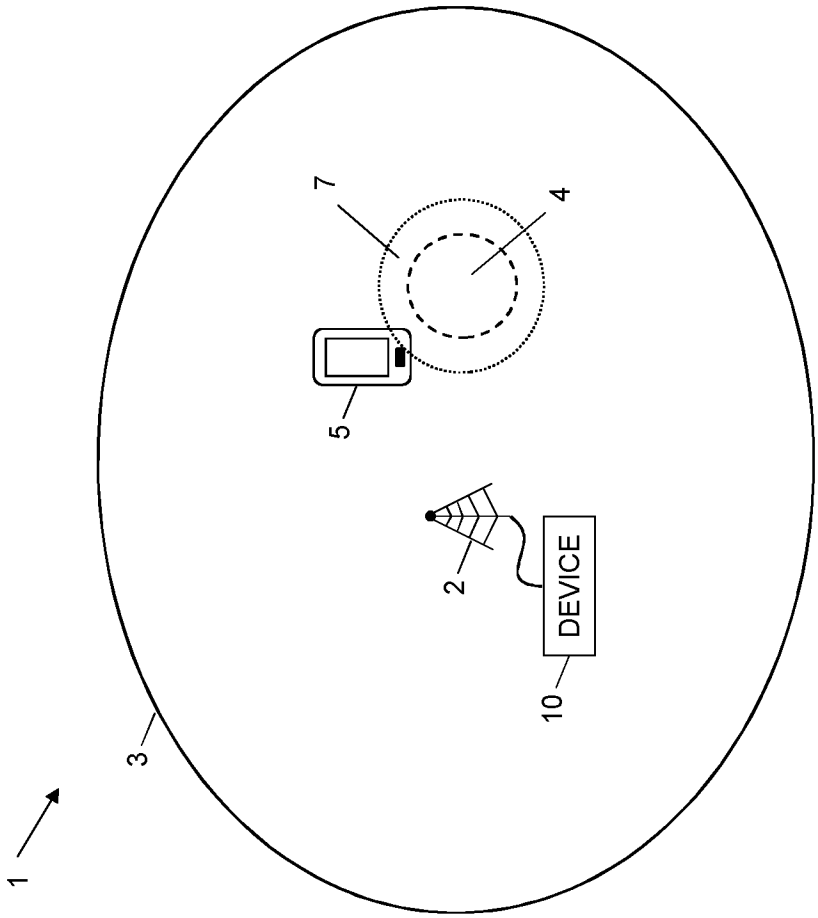

Fig. 8

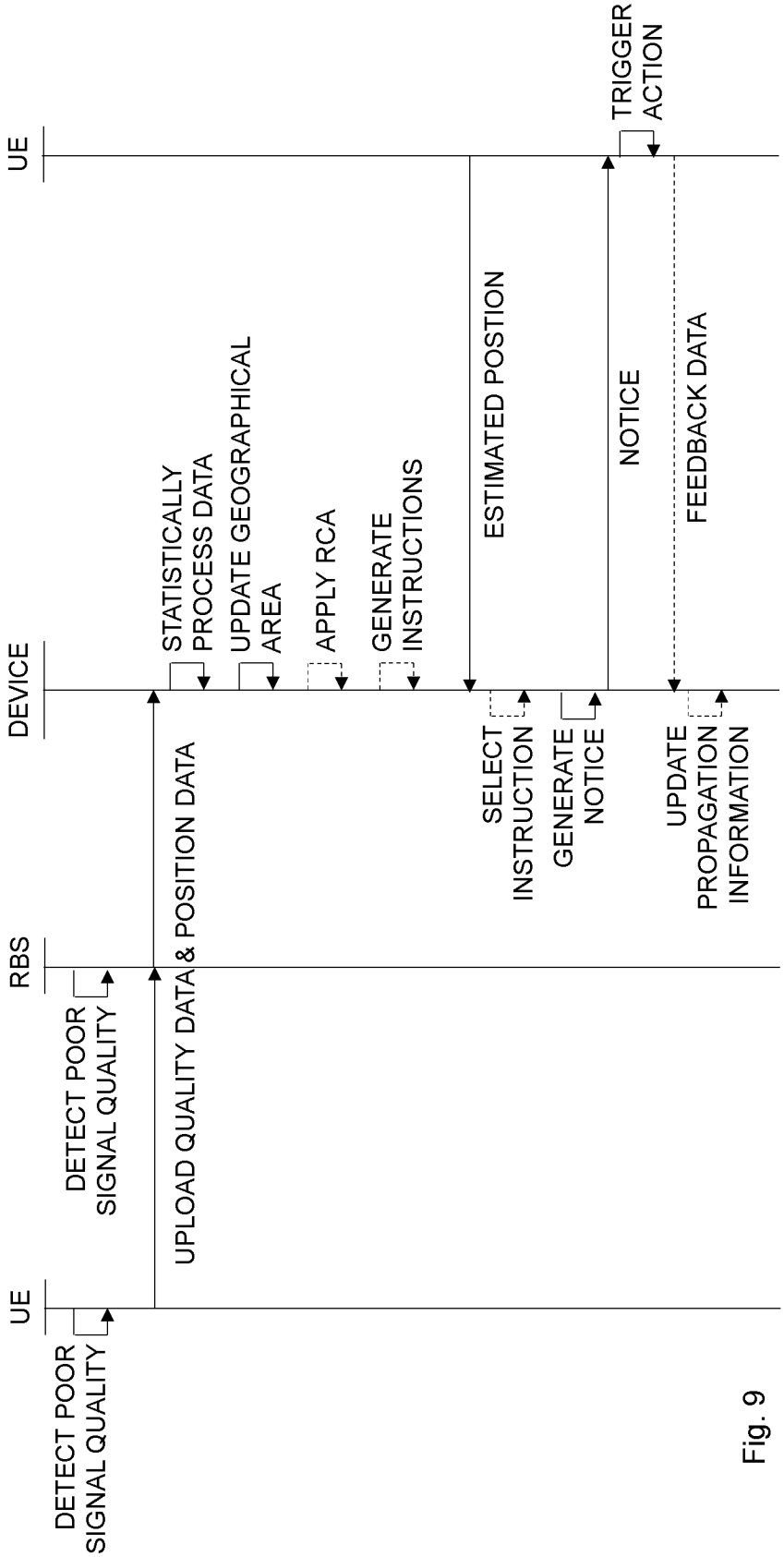
UE
RBS
DEVICE
UE
DETECT POOR SIGNAL QUALITY
DETECT POOR SIGNAL QUALITY
UPLOAD QUALITY DATA & POSITION DATA
STATISTICALLY PROCESS DATA
UPDATE GEOGRAPHICAL AREA
APPLY RCA
GENERATE INSTRUCTIONS
ESTIMATED POSTION
SELECT INSTRUCTION
GENERATE NOTICE
NOTICE
TRIGGER ACTION
UPDATE PROPAGATION INFORMATION
FEEDBACK DATA

Fig. 9

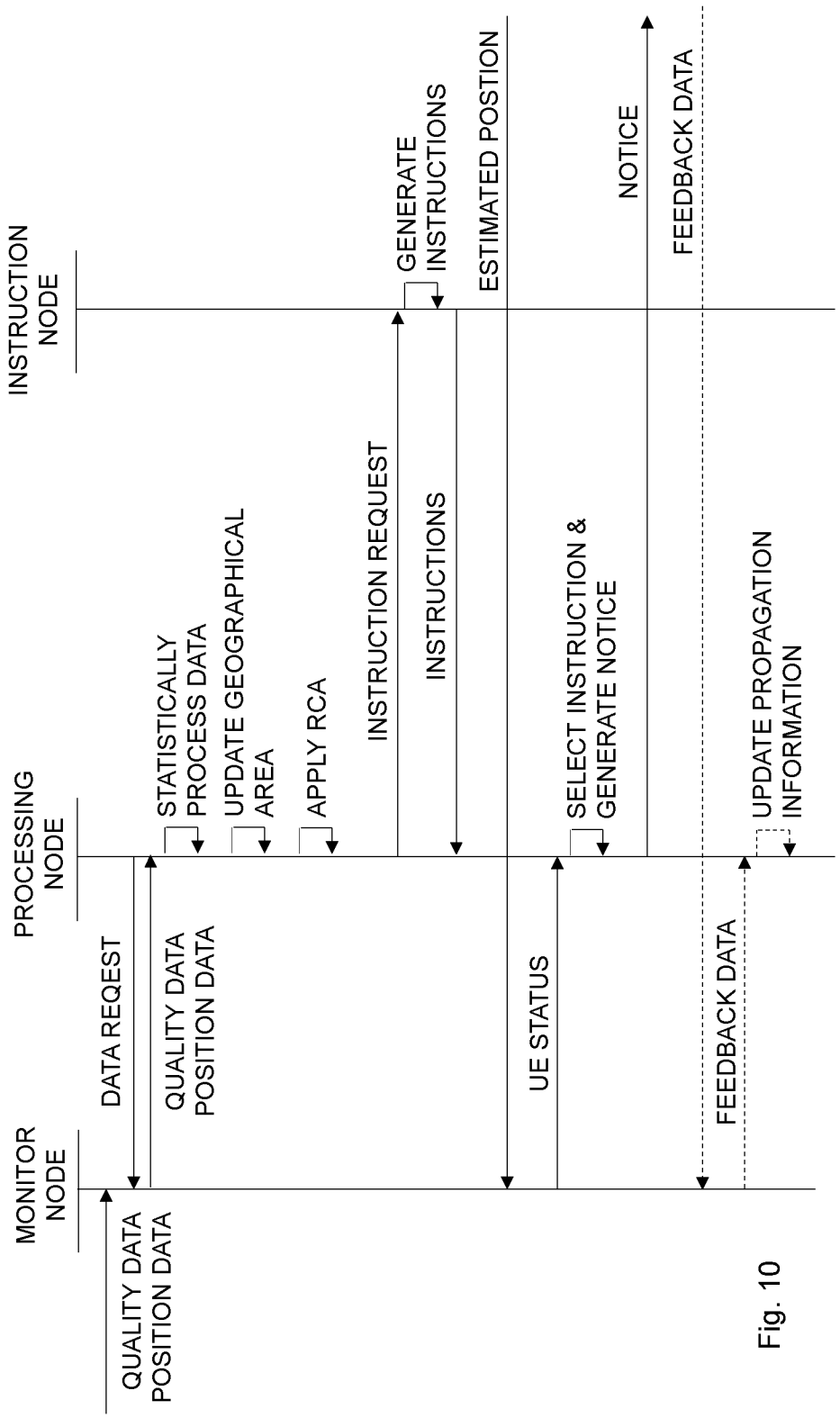
MONITOR NODE
PROCESSING NODE
INSTRUCTION NODE
QUALITY DATA POSITION DATA
DATA REQEST
QUALITY DATA POSITION DATA
STATISTICALLY PROCESS DATA
UPDATE GEOGRAPHICAL AREA
APPLY RCA
INSTRUCTION REQUEST
GENERATE INSTRUCTIONS
INSTRUCTIONS
ESTIMATED POSTION
UE STATUS
SELECT INSTRUCTION & GENERATE NOTICE
NOTICE
FEEDBACK DATA
FEEDBACK DATA
UPDATE PROPAGATION INFORMATION

Fig. 10

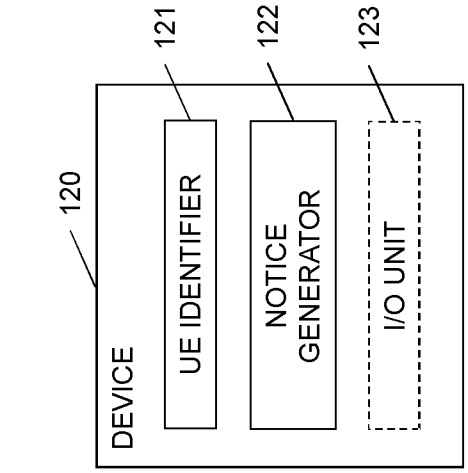

Fig. 13

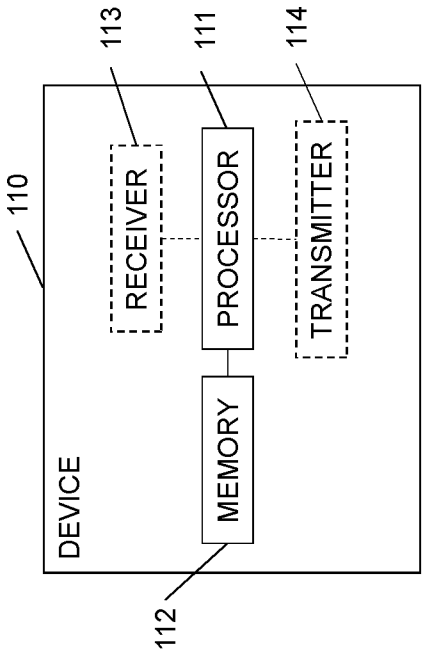

Fig. 12

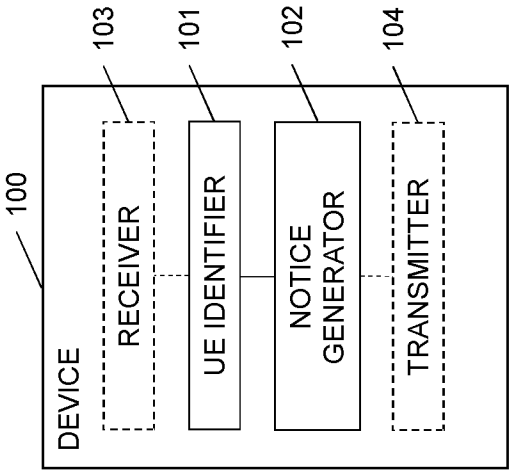

Fig. 11

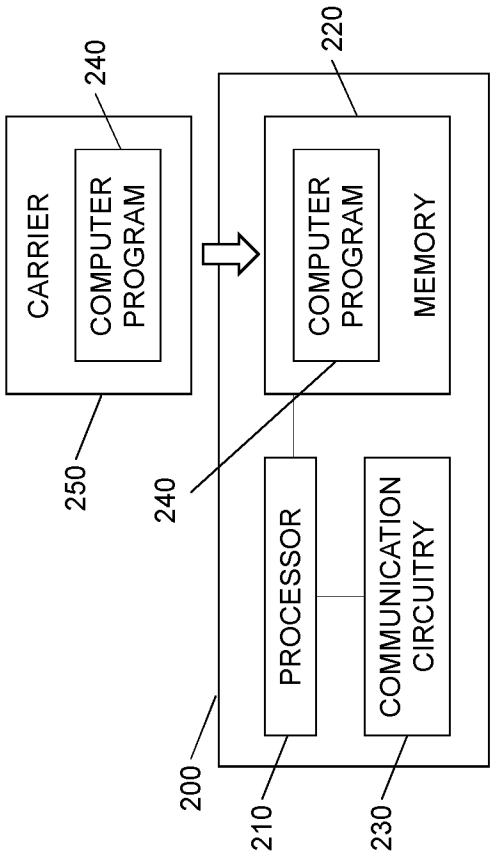
CARRIER
COMPUTER PROGRAM
240
250
220
COMPUTER PROGRAM
MEMORY
240
PROCESSOR
COMMUNICATION CIRCUITRY
200
210
230

Fig. 15

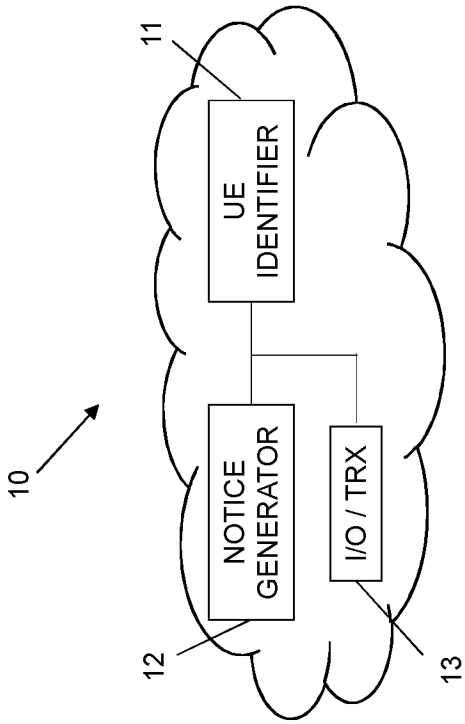
10
11
UE IDENTIFIER
NOTICE GENERATOR
I/O / TRX
12
13

Fig. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2015/050778

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W4/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 703 757 A1 (CIT ALCATEL [FR]) 20 September 2006 (2006-09-20)	1-4,6-8, 11,12, 19-25
Y	paragraphs [0001], [0008], [0010] - [0011], [0015], [0017], [0020], [0022], [0024], [0034], [0037]; claims 1-5 -----	9,10
X	EP 2 273 821 A1 (ALCATEL LUCENT [FR]) 12 January 2011 (2011-01-12) paragraphs [0005], [0006], [0009], [0012]; claims 1-10 -----	1-4,6-8, 10-12, 19-25
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 February 2016	18/05/2016

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

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2015/050778

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/075676 A1 (HYZIAK JANUSZ [US] ET AL) 25 March 2010 (2010-03-25) paragraphs [0002] - [0004], [0014] - [0015] -----	1-8, 10-13, 19-25
X	GB 2 481 715 A (VODAFONE PLC [GB]) 4 January 2012 (2012-01-04) page 3, line 25 - page 10, line 10 page 46 page 51 -----	10
Y	WO 2013/010565 A1 (NOKIA SIEMENS NETWORKS OY [FI]; WEGMANN BERNHARD [DE]; VIERING INGO [D) 24 January 2013 (2013-01-24) page 1, line 31 - page 2, line 32 page 4, lines 26-30 page 7, lines 19-23 page 20, line 29 - page 21, line 16 -----	9
Y	US 2013/121194 A1 (HESHMATI ARDALAN [US]) 16 May 2013 (2013-05-16) abstract -----	10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2015/050778

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-13, 19-25

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-13, 19-25

   Management of persistent poor radio signal propagation in a radio communication network. A User Equipment UE that is going to enter a region of poor coverage is identified and instructions are sent to the UE in order to compensate for the poor radio conditions. The decision may be based on the location, speed and direction and the instructions modify the behavior of the UE.

   ---

2. claims: 14-18

   Management of persistent poor radio signal propagation in a radio communication network. A User Equipment UE that is going to enter a region of poor coverage is identified and instructions are sent to the UE in order to compensate for the poor radio conditions. The network receives statistical information in order to determine the region with poor coverage.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2015/050778

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 1703757	A1	20-09-2006	AT	385392	T	15-02-2008
			CN	1838826	A	27-09-2006
			DE	602005004599	T2	05-03-2009
			EP	1703757	A1	20-09-2006
			JP	2006262463	A	28-09-2006
			US	2006211418	A1	21-09-2006
EP 2273821	A1	12-01-2011	CN	102474791	A	23-05-2012
			EP	2273821	A1	12-01-2011
			JP	2012531861	A	10-12-2012
			KR	20120042881	A	03-05-2012
			US	2012165025	A1	28-06-2012
			WO	2011000512	A1	06-01-2011
US 2010075676	A1	25-03-2010	NONE			
GB 2481715	A	04-01-2012	NONE			
WO 2013010565	A1	24-01-2013	NONE			
US 2013121194	A1	16-05-2013	NONE			