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(54) **Title**: MAKING HANDOVER DECISIONS IN A WIRELES NETWORK

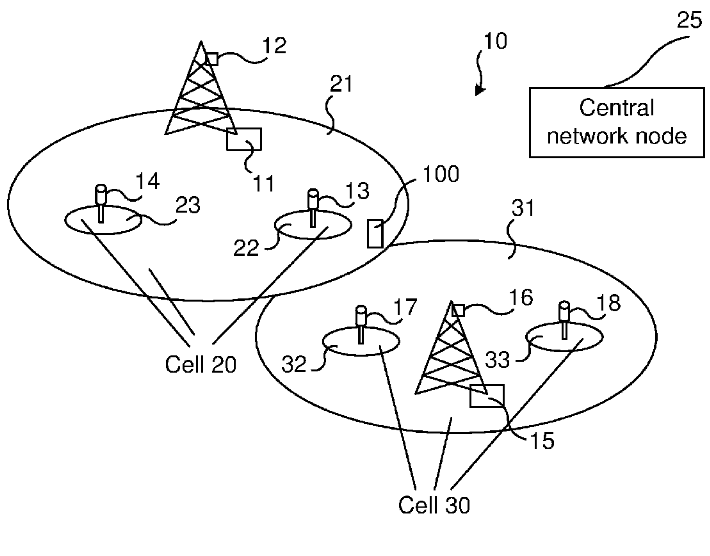

Fig. 2

(57) Abstract: The disclosure relates to a method (40) performed in a wireless network (10) for making a handover decision for a communication device (100) served by a network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23). The method (40) comprises: receiving (42), from the communication device (100), a first measurement report relating to channel conditions towards the serving cell (20) and/or towards a neighboring cell (30); configuring (44) the communication device (100) to measure on channel state information reference signal, CSI-RS, resources used by sectors (31, 32, 33) of the neighboring cell (30); receiving (45), from the communication device (100), channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources; and making (47) a handover decision based on the received CSI measurement reports. The disclosure relates to corresponding wireless network (10), to method in network node, network node, computer programs and computer program products.

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MAKING HANDOVER DECISIONS IN A WIRELES NETWORK

Technical field

The technology disclosed herein relates generally to the field of wireless networks, and in particular to handover decisions in such wireless networks.

Background

In a Long Term Evolution (LTE) deployment a number of network nodes, denoted evolved NodeBs (eNodeBs) or eNBs, are deployed to provide coverage in certain geographic areas, denoted cells. Each eNodeB can manage a set of cells and also manage all wireless devices, in the following denoted user equipment (UE), residing in the coverage area of those cells.

From the UE perspective, the cells are distinguished by a physical-layer cell identity (PCI). In a typical deployment scenario, neighboring cells have different PCIs and when UEs are in a connected state, as opposed to idle state, they use these PCIs as an identifier for handover measurements.

Cell Merge, also called shared cell or multi-sector cell in some cases, is a new cell configuration for LTE and enables a multi Radio Resource Unit (RRU) deployment without needing to care about cell planning from a Radio Frequency (RF) perspective. It is achieved by allowing the different RRUs to use the same PCI and thus all RRUs are considered, by the UE, to be part of the same cell. The spatially separated RRUs or a group of RRUs are called sector. A cell can contain multiple sectors, and a UE can belong to one sector or multiple sectors depending on the degree of sector isolation.

Different from a basic LTE cell configuration where all UEs camped in a cell share cell resources by time and/or frequency multiplexing, in a multi-sector cell yet another resource domain is introduced, namely a spatial resource. In space division multiplexing, some UEs that are spatially separated can use the same time and frequency resources, but in different sectors. In some cases, antenna feeders and antenna placement cannot be altered or planned, leading to inter-sector interference, where a UE's transmission can be detected in several sectors. In uplink the received signals detected in the multiple antennas can be selected to be combined in order to obtain macro diversity gain; in downlink, the signal is only transmitted in the selected antennas to enable higher transmission energy.

There are several benefits of such configuration. A first benefit is easy cell planning: all sectors belong to the same cell, so there is no need to care about inter-cell interference. A second benefit is reduced Layer 3 (L3) control signaling because there is no need to perform handover between sectors within one cell. A third benefit is that for the UEs belonging to multiple sectors, macro diversity gain can be achieved in uplink by selectively combining the signals from multiple sectors, and in downlink the eNodeB may selectively transmit in one or multiple sectors. The UE may combine the received signals from transmitted sectors. For the UE belonging to sectors which are spatially isolated, multiplexing different UEs in the same time and frequency resources can be used to improve capacity.

In order to support mobility, a UE needs to continuously search for, synchronize to, and estimate the signal reception quality of both its serving cell and neighbor cells. The signal reception quality of the neighbor cells, in relation to the signal reception quality of the serving cell, is then evaluated by the UE in order to conclude whether conditions is fulfilled for sending an event-triggered measurement report indicating that handover (for UEs in connected mode) or cell re-selection (for UEs in idle mode) should be carried out. For UEs in connected mode, the handover decision is taken by the eNodeB based on measurement reports provided by the UEs. Examples of such reports are reference signal received power (RSRP) and reference signal received quality (RSRQ) measurement results. In current LTE, both RSRP and RSRQ measurements are performed by measuring cell specific reference signals (CRS) which are transmitted by all cells in each subframe.

In a multi-sector cell deployment scenario, mobility measurement is based on the traditional downlink RSRP/RSRQ measurements of CRS from serving and neighboring cells. After the UE is successfully connected to a target cell, new sectors are selected based on the sector selection mechanism in the new cell.

A problem with using these traditional RSRP/RSRQ measurements is a possible pathloss imbalance between uplink and downlink caused by the heterogeneous network deployment.

An example of the above-mentioned problem is described with reference to figure 1. Cell B comprises multiple sectors, and more specifically two sectors: Sector 1 is a macro sector and Sector 2 is a pico sector. Typically, a macro sector has a high transmit power, e.g. 20W, and a pico sector has a low transmit power, e.g. 1W. The transmit power ratio between the macro and pico sector is X=P1/P2={for this example}= 1/20=0.05. Cell A is a single sector macro cell, denoted Sector 3. The transmit power of this macro base station 2 is in this example also 20W.

The UE 1 receives signaling from the two sectors of Cell B and from the single-sector Cell A. A downlink geometry can be determined as downlink power received by the UE 1 in one cell compared to downlink power received in another cell. The downlink geometry is in this case the ratio of RSRP of CRS from Cell A to RSRP of CRS of Cell B, i.e.: $RSRP_A/RSRP_B$. Cell B comprises two sectors, and since the signaling that the UE measures on comes from a shared cell using the same CRS, the UE is unaware of the mix thereof, i.e. $RSRP_B=P_1g_{11}+xP_1g_{21}$, wherein the UE 1 experiences a certain geometry g towards the different cells, and the subscript ij refers to sector i and UE j. Hence:

$$\frac{RSRP_A}{RSRP_B}=\frac{P_1g_{31}}{P_1g_{11}+xP_1g_{21}}=\frac{g_{31}}{g_{11}+xg_{21}} \text{ (Equation 1)}$$

The uplink geometry can be determined as uplink power received from the UE 1 in one cell compared to uplink power received in another cell. The uplink geometry is in this case the ratio of received power $P_{RX,A}$ in Cell A to the received power $P_{RX,B}$ in Cell B: $P_{RX,A}/P_{RX,B}$. This uplink geometry is related to the power P_{TX} transmitted by the UE 1 and the following is obtained:

$$\frac{P_{RX,A}}{P_{RX,B}}=\frac{P_{TX}g_{31}}{P_{TX}g_{11}+P_{TX}g_{21}}=\frac{g_{31}}{g_{11}+g_{21}} \text{ (Equation 2)}$$

For the UE 1 close to the border of two cells, the downlink geometry is assumed to be equal to 1, and Equation 1 gives $g_{31}=g_{11}+xg_{21}$. Equation 2 then gives

$$\frac{g_{11}+xg_{21}}{g_{11}+g_{21}}=\frac{1+(x-1)}{g_{11}+g_{21}}$$

Since $x<1$ also UL geometry < 1, i.e. the actual uplink geometry is lower than 1. That is, the cell B receives at a lower power from the UE 1 than cell A. At handover this indicates a potential uplink problem if the UE 1 moves from cell A to cell B based on the downlink measurement because of the poor connection with the target eNodeB in uplink.

A known solution is to use measured uplink received power in different sector carriers to perform handover. Such measurements comprise for example Physical Random Access Channel (PRACH), Sounding Reference Signals (SRS) or Physical Uplink Control Channel (PUCCH) measurements. Such solution however requires uplink resource allocations in advance and the UE might need to synchronize to a target cell before obtaining resources to measure the uplink quality.

In a multi-sector cell deployment scenario, mobility measurement is based on the traditional downlink ratio of RSRP to RSRQ of CRS from serving and neighboring cells. A problem is the possible pathloss imbalance between uplink and downlink caused by the heterogeneous network deployment. In such a scenario, the downlink RSRP based geometry measurement cannot represent the uplink situation, because this, as shown above, may lead to the uplink signal strength being overestimated. If the handover is triggered based on the downlink RSRP measurement, the UE 1 may therefore experience poor uplink connection when the UE 1 is moved to the target cell, which may lead to handover failure and user dissatisfaction.

Summary

An object of the present disclosure is to solve or at least alleviate at least one of the above mentioned problems.

The object is according to a first aspect achieved by a method performed in a wireless network for making a handover decision for a communication device served by a network node. The network node provides coverage in a serving cell comprising one or more sectors. The method comprises receiving, from the communication device, a first measurement report relating to channel conditions towards the serving cell; configuring the communication device to measure on channel state information reference signal, CSI-RS, resources used by sectors of the neighboring cell; receiving, from the communication device, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources; and making a handover decision based on the received CSI measurement reports.

An advantage of the method comprises that the too early handover can be effectively avoided. The too early handover may eventually result in handover failure when the UE is moved to a target network node but the uplink connection with the target network node is not good enough.

The object is according to a second aspect achieved by a wireless network for making a handover decision for a communication device served by a network node. The network node provides coverage in a serving cell comprising one or more sectors .The wireless network is configured to receive, from the communication device, a first measurement report relating to channel conditions towards the serving cell and/or towards a neighboring cell; configure the communication device to measure on channel state information reference signal, CSI-RS, resources used by sectors of the neighboring cell; receive, from the communication device, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources; and make a handover decision based on the received CSI measurement reports.

The object is according to a third aspect achieved by a computer program for a wireless network for making a handover decision for a communication device served by the network node, the network node providing coverage in a serving cell comprising one or more sectors. The computer program comprises computer program code, which, when executed on at least one processor of the wireless network causes the wireless network to perform the method as described above.

The object is according to a fourth aspect achieved by a computer program product comprising a computer program as above and a computer readable means on which the computer program is stored.

The object is according to a fifth aspect achieved by a method performed in a network node for effectuating a handover decision for a communication device served by the network node. The network node provides coverage in a serving cell comprising one or more sectors. The method comprises receiving a first measurement report from the communication device relating to channel conditions towards the serving cell and/or towards a neighboring cell; receiving from the communication device channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30; effectuating a handover decision based on the received CSI measurement reports.

The object is according to a sixth aspect achieved by a network node for effectuating a handover decision for a communication device served by the network node. The network node provides coverage in a serving cell comprising one or more sectors. The network node is configured to receive a first measurement report from the communication device relating to channel conditions towards the serving cell and/or towards a neighboring cell; receive from the communication device channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30; and effectuate a handover decision based on the received CSI measurement reports.

The object is according to a seventh aspect achieved by a computer program for a network node for effectuating a handover decision for a communication device served by the network node. The network node provides coverage in a serving cell comprising one or more sectors. The computer program comprises computer program code, which, when executed on a processor of the network node causes the network node to perform the method as above.

The object is according to an eight aspect achieved by a computer program product comprising a computer program as above and a computer readable means on which the computer program is stored.

Further aspects, features and advantages of the present disclosure will become clear upon reading the following description and the accompanying drawings.

Brief description of the drawings

Figure 1 illustrates uplink and downlink geometries in a heterogeneous environment.

Figure 2 illustrates schematically an environment in which embodiments of the present disclosure may be implemented.

Figure 3 illustrates a flow chart over steps of a method in a network in accordance with the present disclosure.

Figure 4 illustrates schematically a network and means for implementing methods of the present disclosure.

Figure 5 illustrates a network comprising function modules/software modules for implementing methods of the present disclosure.

Figure 6 illustrates a flow chart over steps of a method in a network node in accordance with the present disclosure.

Figure 7 illustrates a network comprising function modules/software modules for implementing methods of the present disclosure.

Detailed description

In the following description, for purposes of explanation and not limitation, specific details are set forth such as particular architectures, interfaces, techniques, etc. in order to provide a thorough understanding. In other instances, detailed descriptions of well-known devices, circuits, and methods are omitted so as not to obscure the description with unnecessary detail. Same reference numerals refer to same or similar elements throughout the description.

Briefly, in accordance with an aspect of the present disclosure, after receiving a measurement report from a UE based on RSRP differences, the UE is, instead of being triggered to do a handover, configured to receive multiple Channel State Information Reference Signal (CSI-RS) resources transmitted in both serving cell and the neighboring cells, or only in the neighboring cells. The UE feedbacks the CSI measurement results based on these CSI-RS resources. Then the wireless network, e.g. a serving eNB thereof, derives the signal strength of each measured CSI-RS resource that is transmitted by different sectors from the received CSI measurements. By comparing the signal strength of serving sector(s) with the sector(s) that belong to the neighboring cell, the eNB decides whether handover of the UE should be initiated towards the neighbor cell.

Figure 2 illustrates schematically an environment in which embodiments of the present disclosure may be implemented. A wireless network 10 comprises various network nodes 11, 15 providing wireless communication for communication devices 100. The wireless network 10 may for instance be a Long Term Evolution (LTE) network, and the network nodes 11, 15 enabling the communication devices 11, 15 to communicate over wireless links are in the following denoted evolved nodeB (eNB) 11, 15. It is however noted that such network nodes 11, 15 may be denoted in different ways, e.g. radio access node, base station, radio base station, evolved node B (eNB) etc. The eNB provides coverage within a certain geographic area, denoted cell. Also the communication device 100 may be denoted in different ways, e.g. mobile station, wireless device, user equipment (UE), etc. The communication device 100 is in the following denoted UE 100 and may comprise e.g. a smart phone, a tablet etc.

The wireless network 10 further typically comprises various other network nodes, such as Mobility Management Entity (MME), operation and maintenance (O&M) nodes, packet data network gateways, mobility management entities, serving gateways etc. One such other network node is illustrated as central network node with reference numeral 25. Aspects of the present disclosure may be implemented in such central network node 25.

A first network node 11 is the serving network node for a UE 100, wherein a network node may be considered a serving network node when the UE is within its cell(s). In the following this first network node 11 is denoted serving eNB 11. The serving eNB 11 comprises a first cell 20 comprising three sectors: a first sector 21, a second sector 22 and a third sector 23. The first cell 20 is in the following also denoted serving cell 20. A second network node 15 is a neighboring network node to the first network node 11, and is in the following denoted neighboring eNB 15. The neighboring eNB 15 provides coverage in a second cell 30 comprising three sectors: a third sector 31, a fourth sector 32 and fifth sector 33. The second cell 30 is in the following also denoted neighboring cell 30. The wireless network 10 may comprise any number of such cells 20, 30, wherein each cell 20, 30 may comprise one or multiple sectors. Each sector 21, 22, 23; 31, 32, 33 of a cell 20; 30 comprises reception means 12, 13, 14; 16, 17, 18 for receiving signaling from the UE 100 and for transmitting signaling to the UE 100. Such reception means may for instance comprise one or more antenna arrays and transceiver circuitry. It is noted that a neighboring eNB may be neighboring eNB for a first set of UEs and serving eNB for a second set of UEs; i.e., an eNB may be both a serving and a neighboring node, for different UEs. It is also noted that one eNB may control several cells, for example a serving cell and a neighboring cell, each cell comprising one or more sectors.

From LTE Release 10 and onwards, a new reference signal (RS) concept was introduced for the purpose of receiving channel state information (CSI) feedback from the UE. This reference signal is also referred to as CSI-RS. CSI-RS are not transmitted in every subframe and they are generally sparser in time and frequency than RS used for demodulation. CSI-RS transmissions may for instance occur every 5th, 10th, 20th, 40th, or 80th subframe according to a Radio Resource Control (RRC) configured periodicity and an RRC configured subframe offset.

In a multi-sector cell as described above, each sector may transmit a CSI-RS resource which can be seen as a pattern of resource elements on which a particular CSI-RS configuration is used. A CSI-RS resource is determined by a combination of the parameters resourceConfig, subframeConfig and antennaPortsCount which are configured by the RRC signaling. Reference is also made to e.g. TS 36.311 and TS 36.211 for RRC parameters and Layer 1 (L1) parameters..

A CSI process is associated with a CSI-RS resource and a CSI-Interference Measurement (IM) resource. A CSI reported by the UE 100 corresponds to a CSI process configured by the serving eNB 11. The UE 100 may be configured with one or more CSI processes per cell.

The present disclosure takes advantage of the CSI-RS for improving the conventional handover decisions. In the following a number of steps are described, which may be combined to obtain various embodiments of the present disclosure.

Step 1

After a RRC connection setup, the UE 100 is configured with known measurement report triggering events. This RRC may for instance be performed by the serving eNB 11. That is, the UE 100 is configured by means of a RRC message with criteria used by the UE 100 to trigger the transmission of a measurement report; i.e. configuring the UE 100 to know when to send the measurement report. An example of such known measurement report triggering events comprises when the neighboring cell becomes offset better than primary cell (PCell). This is known as LTE measurement report triggering A3. Another example comprises the primary cell (PCell) becoming worse than a defined first threshold and neighboring becoming better than a defined second threshold. This is known as LTE measurement report triggering A5. Upon such report triggering event being fulfilled, the UE 100 sends a measurement report. The UE 100 performs the conventional RSRP/RSRQ measurements (described earlier) on the serving cell 20 and on the neighboring cell 30. The UE 100 triggers a transmission of the measurement report if the event triggering criterion (e.g. A3 or A5) is fulfilled. This is in accordance with existing measurement procedure.

In a similar fashion event A6 can be used for starting CSI-RS evaluation on which sectors to use for Secondary Cell (SCell) transmission on SCell frequencies.

A PCell is the cell that the UE selects during initial establishment, while one or more SCell(s) may be added/deleted by the wireless network 10, e.g. by the serving eNB 11.

Step 2

Upon reception of the above measurement report, the wireless network 10, e.g. the serving eNB 11 or the central network node 25, configures the UE 100 to measure on the CSI-RS resources that are used by sectors 31, 32, 33 of the neighboring cell 30. The information of CSI-RS resources used in the neighboring cell 30 may for instance be obtained through Operation and Maintenance (O&M) configuration or via an X2 eNB configuration exchange between the serving eNB 11 and the neighboring eNB 15. If the serving eNB controls both the serving cell and neighboring cell, then no X2 communication is needed as it has all information on its CSI-RS resources. The configured CSI-RS resources are to be used for measuring the channel quality from the sectors 21, 22, 23 of the serving cell 20 and for measuring the channel quality from the sectors 31, 32, 33 of the neighboring cell 30. In another embodiment, the UE 100 is configured with CSI-RS resources for the neighboring cell 30 only, and other measurements are used to measure the channel quality in the one or more sectors of the serving cell 20. Examples of such other measurements comprise uplink measurements on SRS, PRACH, Physical Uplink Shared Channel (PUSCH) and PUCCH.

As an example, the wireless network 10, e.g. the serving eNB 11 or the central network node 25, may configure a CSI process for the UE 100, where the UE 100 can measure the CSI-RS resources from different sectors of different cells but wherein CSI-IM measurements use the same interference hypothesis.

Step 3

The UE 100 performs the CSI measurements on all configured CSI-RS resources and reports the measured results to the wireless network 10, e.g. to the serving eNB 11, or to the central network node 25 via the serving eNB 11.

Step 4

The wireless network 10, e.g. the serving eNB 11, collects the CSI measurement results provided by the UE 100 on all CSI-RS resources from different sectors 21, 22, 23, 31, 32, 33 and derives the signal strength of these CSI-RS resources. The CSI measurement report received from cell i and sector j can be written:

$$CSI_{i,j} = \frac{P_{i,j}}{I+n} = \frac{X_{i,j} G_{i,j} P}{I+n}$$

, where $CSI_{i,j}$ is a channel quality measurement of the UE 100 from sector j in cell i, $P_{i,j}$ is the received power in the UE 100 from sector j in cell i and $I+n$ is the noise plus interference power the UE 100 measured in the same CSI-IM resource. $X_{i,j}$ is the power offset between the transmit power of the sector j in cell i with reference power P and it is known by wireless network 10, e.g. by the serving eNB 11. $G_{i,j}$ is the path gain from sector j in cell i to the UE 100 of interest. The serving eNB 11 will receive a set of CSI measurements from the serving cell 20 and/or from the neighboring cell 30.

The wireless network 10, e.g. the serving eNB 11, performs filtering in time and the filtered CSI result can be written as $\overline{CSI_{i,j}}$. Assuming that the filtered long term uplink path gain is equal to the downlink path gain, the uplink path gain can be obtained by:

$$G_{i,j}^{UL} = \frac{CSI_{i,j} \cdot (I+n)}{X_{i,j} \cdot P}$$

Assuming that there are three sectors in each cell, a first cell denoted cell 1 and a second cell denoted cell 2, the relative difference between uplink channel gain from different sectors in different cells can be written as (subscripts i,j indicating cell i, sector j):

$$G_{1,1}^{UL} : G_{1,2}^{UL} : G_{1,3}^{UL} = \frac{\overline{CSI_{1,1}}}{X_{1,1}} : \frac{\overline{CSI_{1,2}}}{X_{1,2}} : \frac{\overline{CSI_{1,3}}}{X_{1,3}}$$

$$G_{2,1}^{UL} : G_{2,2}^{UL} : G_{2,3}^{UL} = \frac{\overline{CSI_{2,1}}}{X_{2,1}} : \frac{\overline{CSI_{2,2}}}{X_{2,2}} : \frac{\overline{CSI_{2,3}}}{X_{2,3}}$$

Relating this to the wireless network 10 of figure 2: $G_{1,1}^{UL}$ would thus be the uplink channel gain in the first sector 21 of the first cell 20; $G_{1,2}^{UL}$ would be the uplink channel gain in the second sector 22 of the first cell 20; $G_{1,3}^{UL}$ would be the uplink channel gain in the third sector 23 of the first cell 20. $G_{2,1}^{UL}$ would thus be the uplink channel gain in the fourth sector 31 of the second cell 30; $G_{2,2}^{UL}$ would be the uplink channel gain in the fifth sector 32 of the second cell 30; $G_{1,3}^{UL}$ $G_{1,2}^{UL}$ would be the uplink channel gain in the sixth sector 33 of the second cell 30.

Step 5

The wireless network 10, e.g. the serving eNB 11 or the central node 25, compares the calculated uplink path gain of the sector(s) 21, 22, 23 of the serving cell 20 with uplink path gain of the sectors 31, 32, 33 of the neighboring cell 30 in order to determine whether handover to the neighboring cell 30 is required. The handover trigger could be based on the below comparisons dependent on the current condition, e.g.:

Alt 1: max ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) < max ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$)

That is, the calculated path gains of the sectors of a first cell (e.g. serving cell 20) is compared to the calculated path gains of a sectors of a second cell (e.g. neighboring cell 30), and if the maximum path gain of a sector of the first cell is smaller than the maximum path gain of a sector of the second cell, then handover is to be made.

Alt 2: min ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) <max ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$)

That is, the calculated path gains of the sectors of a first cell (e.g. serving cell 20) is compared to the calculated path gains of a sectors of a second cell (e.g. neighboring cell 30), and if the minimum path gain of a sector of the first cell is smaller than the maximum path gain of a sector of the second cell, then handover is to be made.

Alt 3: max ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) < min ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$)

That is, the calculated path gains of the sectors of a first cell (e.g. serving cell 20) is compared to the calculated path gains of a sectors of a second cell (e.g. neighboring cell 30), and if the maximum path gain of a sector of a first cell is smaller than the minimum path gain of a sector of a second cell, then handover is to be made.

Alt 4: min ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) <min ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$)

That is, the calculated path gains of the sectors of a first cell (e.g. serving cell 20) is compared to the calculated path gains of a sectors of a second cell (e.g. neighboring cell 30), and if the minimum path gain of a sector of the first cell is smaller than the minimum path gain of a sector of the second cell, then handover is to be made.

Alt 5: Avg ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) <Avg ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$)

That is, the calculated average path gains of the sectors of a first cell (e.g. serving cell 20) is compared to the average calculated path gains of a sectors of a second cell (e.g. neighboring cell 30), and if the average path gain of a sector of the first cell is smaller than the average path gain of a sector of the second cell, then handover is to be made.

It is noted that $G_{1,1}^{UL}$, $G_{1,2}^{UL}$, $G_{1,3}^{UL}$ may be the calculated uplink path gain from the sectors 21, 22, 23 in serving cell 20 while $G_{2,1}^{UL}$, $G_{2,2}^{UL}$, $G_{2,3}^{UL}$ may represent the calculated uplink path gain from the sectors 31, 32, 33 belonging to a neighbor cell 30.

In a manner corresponding to prior art, offset and Time to trigger protection against ping pong handover (hysteresis) can be added to the comparison. For instance, event A3 offset and time to trigger are existing mechanisms used in Radio Resource Management (RRM) measurement in order to ensure that the measurement report received by the eNB are as reliable as possible. Similar principles of using offset and time to trigger may be used in the CSI measurement on different CSI-RS resources. For instance, when calculating the path gain, the eNB may add an offset value to the received CSI results. For time to trigger, one example is to add an extra time to prolong the CSI reporting periodicity (for periodic CSI) or an extra time to send aperiodic CSI report grant (for aperiodic CSI reporting.

Downlink handover criteria be based on prior art solution (Alt. 1 below) or based for instance on per sector filtered CSI reports (Alt. 2-6 below).

Alt1: RSRP1<RSRP2

That is, the RSRP of a first cell (e.g. serving cell 20) is compared to the RSRP of a second cell (e.g. neighboring cell 30), and if the criteria is fulfilled, then handover is made to the second cell.

Alt2: $\max(\overline{CSI_{1,1}}, \overline{CSI_{1,2}}, \overline{CSI_{1,3}}) < \max(\overline{CSI_{2,1}}, \overline{CSI_{2,2}}, \overline{CSI_{2,3}})$

That is, the per sector filtered CSI reports of a first cell (e.g. serving cell 20) is compared to the per sector filtered CSI reports of a second cell (e.g. neighboring cell 30), and if the maximum per sector filtered CSI report of the first cell is smaller than the maximum per sector filtered CSI report of the second cell, then handover is to be made.

Alt3: $\max(\overline{CSI_{1,1}}, \overline{CSI_{1,2}}, \overline{CSI_{1,3}}) < \min(\overline{CSI_{2,1}}, \overline{CSI_{2,2}}, \overline{CSI_{2,3}})$

That is, the per sector filtered CSI reports of a first cell (e.g. serving cell 20) is compared to the per sector filtered CSI reports of a second cell (e.g. neighboring cell 30), and if the maximum per sector filtered CSI report of the first cell is smaller than the minimum per sector filtered CSI report of the second cell, then handover is to be made.

Alt4: $\min(\overline{CSI_{1,1}}, \overline{CSI_{1,2}}, \overline{CSI_{1,3}}) < \max(\overline{CSI_{2,1}}, \overline{CSI_{2,2}}, \overline{CSI_{2,3}})$

That is, the per sector filtered CSI reports of a first cell (e.g. serving cell 20) is compared to the per sector filtered CSI reports of a second cell (e.g. neighboring cell 30), and if the minimum per sector filtered CSI report of the first cell is smaller than the maximum per sector filtered CSI report of the second cell, then handover is to be made.

Alt5: $\min(\overline{CSI_{1,1}}, \overline{CSI_{1,2}}, \overline{CSI_{1,3}}) < \min(\overline{CSI_{2,1}}, \overline{CSI_{2,2}}, \overline{CSI_{2,3}})$

That is, the per sector filtered CSI reports of a first cell (e.g. serving cell 20) is compared to the per sector filtered CSI reports of a second cell (e.g. neighboring cell 30), and if the minimum per sector filtered CSI report of the first cell is smaller than the minimum per sector filtered CSI report of the second cell, then handover is to be made.

Alt6: $\text{Avg}(\overline{CSI_{1,1}}, \overline{CSI_{1,2}}, \overline{CSI_{1,3}}) < \text{Avg}(\overline{CSI_{2,1}}, \overline{CSI_{2,2}}, \overline{CSI_{2,3}})$

That is, the average of the per sector filtered CSI reports of a first cell (e.g. serving cell 20) is compared to the average of the per sector filtered CSI reports of a second cell (e.g. neighboring cell 30), and if the average of the per sector filtered CSI reports of the first cell is smaller than the average of the per sector filtered CSI reports of the second cell, then handover is to be made.

The final handover decision can be made when either or both uplink and downlink handover criteria are met. Which alternative to choose depends on the scenario at hand. That is, the decision may be based on the actual handover scenario for the particular case, for instance based on whether the source and target cells are sector cells or not. Other examples on which the decision may depend comprise the location of sectors and the relative location of the UE to these sectors.

The above exemplary handover triggering criteria, i.e. the uplink and downlink criteria, may be combined in many different ways. One possible handover decision based on the above triggering criteria examples comprise:

If (RSRP1<RSRP2 is true) AND (max ($G_{1,1}^{UL}, G_{1,2}^{UL}, G_{1,3}^{UL}$) < max ($G_{2,1}^{UL}, G_{2,2}^{UL}, G_{2,3}^{UL}$) is true)

handover is performed and handover command is sent to the UE,

end

The wireless network 10, e.g. the serving eNB 11, may also use a parameter for controlling the maximum amount of sectors that the UE 100 should be able to use.

The various features of the embodiments described may be combined in different ways, also in ways not explicitly mentioned herein.

Figure 3 illustrates a flow chart over steps of a method 40 in a wireless network 10 in accordance with the present disclosure. Boxes drawn with dashed lines indicate optional steps. The method 40 may be performed in a wireless network 10 for making a handover decision for a communication device 100 served by a network node 11, i.e. a serving network node 11. The network node 11 provides coverage in a serving cell 20 comprising one or more sectors 21, 22, 23.

The method 40 comprises receiving 42, from the communication device 100, a first measurement report relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30. The receiving 42 of the first measurement report may be performed by the serving network node 11 and handled therein, or be received by the serving network node 11 and be forwarded to a central network node 25, for further use by the central network node 25.

The method 40 comprises configuring 44 the communication device 100 to measure on channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30. The configuration of the communication device 100 may be performed in the serving network node 11 or in the central network node 25. A network node communicating wirelessly with the communication device 100 may convey radio resource configuration message(s) to communication device 100 comprising the configuration(s). The CSI-RS resources may be configured only for use by sectors 31, 32, 33 of the neighboring cell 30.

The method 40 comprises receiving 45, from the communication device 100, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources.

The method 40 comprises making 47 a handover decision based on the received CSI measurement reports. The handover decision may be performed in the serving network node 11 or in a central network node 25. If performed in a central network node 25, the CSI measurement reports received e.g. at the serving network node 11 are transmitted to the central network node 25 for enabling it to make the handover decision.

In an embodiment, the configuring 44 further comprises configuring the communication device 100 to measure on channel state information reference signal, CSI-RS, resources used by sectors 21, 22, 23 of the serving cell 20. That is, in this embodiment, the UE 100 is configured to receive multiple CSI-RS resources transmitted in both the serving cell and the neighboring cell(s). The UE 100 may then measure on the received CSI-RS resources and report to the wireless network 10, e.g. to the serving network node 11.

It is noted that the serving cell 20 may have access to uplink measurements by means of which it is able to determine the respective contributions from each sector. Alternatively, different types of uplink measurements may be used for measuring uplink channel quality from the one or more sectors of the serving cell 20.

In an embodiment, the first measurement report comprises the ratio of reference signal received power, RSRP1, to reference signal received quality, RSRQ1, of reference signals from the serving cell 20 and ratio of reference signal received power, RSRP2, to reference signal received quality, RSRQ2, of reference signals from the neighboring cell 30.

In an embodiment, the method 40 comprises, prior to the configuring 44, establishing (43) a need for CSI-RS measurements.

In a variation of the above embodiment, the establishing 43 a need for CSI-RS measurements comprises establishing that the communication device 100 is approaching a border between the serving cell 20 and the neighboring cell 30.

In an embodiment, the making 47 a handover decision comprises making the handover decision based on comparison of signal strengths of sectors 21, 22, 23 of the serving cell 20 and signal strengths of sectors 31, 32, 33 of the neighboring cell 30. As noted earlier, the wireless network 10, e.g. the serving network node 11 thereof, may have knowledge on such signals strengths of its sectors 21, 22, 23 without the need for the UE to measure on CSI-RS resources in theses sectors 21, 22, 23.

In an embodiment, the method 40, comprises, prior to the making 47 a handover decision, calculating 46 values of one or more of: uplink path gains of the sectors 21, 22, 23 of the serving cell 20, uplink path gains of the sectors 31, 32, 33 of the neighboring cell 30, per sector filtered CSI measurement reports for sectors 21, 22, 23 of the serving cell 20, and per sector filtered CSI measurement reports for sectors 31, 32, 33 of the neighboring cell 30.

In a variation of the above embodiment, the making 47 a handover decision comprises using the calculated values for establishing if uplink handover criteria and/or downlink handover criteria are met, and making the handover if the uplink handover criteria and/or downlink handover criteria are met. As described and exemplified earlier, various combinations of uplink handover criteria and/or downlink handover criteria may be used as basis for making the handover decision.

In an embodiment, the method 40 comprises, prior to the receiving 42 the first measurement report from the communication device 100, configuring 41 the communication device 100 with a triggering criterion for triggering the communication device 100 to transmit the first measurement report upon fulfilment of the triggering criterion. The configuration of the communication device 100 may, as indicated earlier, be performed in the serving network node 11 or in the central network node 25. A network node communicating wirelessly with the communication device 100 may convey radio resource configuration message(s) to communication device 100 comprising the configuration(s).

In an embodiment, the method 40 is performed in a network node 11 of the wireless network 10. A single network node 11 of the wireless network 10 may be arranged to (e.g. configured to) perform the steps of the various embodiments. In other embodiments, different nodes of the wireless network 10 are arranged to perform one or more steps of the method 40.

In an embodiment, the receiving 42 from the communication device 100, a first measurement report, and the receiving 45, from the communication device 100, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources, are performed in the serving network node 11, and wherein the configuring 44 the communication device 100 to measure on channel state information reference signal, CSI-RS, resources and making 47 the handover decision are made in a central network node 25. The serving network node 11 and the central network node 25 would then need to exchange information as required. For instance, for the central network node 25 to be able to make the handover decision, it would need the results of the measurements made by the communication device 100, which may thus be communicated from the serving network node 11 to the central network node 25. Even if radio resource configuration (RRC) handling is performed in the central network node 25, the actual transmission of RRC messages may be effectuated by the serving network node 11, i.e. the central network node 25 would need to convey the configuration(s) of the communication device 100 to the serving network node 11. This embodiment is thus an example wherein two nodes of the wireless network 10 are involved in the method 40, i.e. cooperating for performing the different steps of the method 40.

Figure 4 illustrates schematically a wireless network 10 and means for implementing methods of the present disclosure.

The wireless network 10 comprises at least one processor 50, 60. The figure 4 illustrates an example wherein a network node 11 serving a UE 100 and a central network node 25 each comprises a respective processor 50, 60. Each of the one or more processors 50, 60 comprise any combination of one or more of a central processing unit (CPU), multiprocessor, microcontroller, digital signal processor (DSP), application specific integrated circuit etc. capable of executing software instructions stored in one or more memories 51, 61, which can thus be a computer program products 51, 61. The processor(s) 50, 60 can be configured to execute any of the various embodiments of the method e.g. as described in relation to figure 3, or together performing the method, wherein one node performs one or more steps of the method and another node performs other steps. The one or more memories 51, 61 may be any combination of random access memory (RAM) and read only memory (ROM). The memory 51, 61 may also comprises persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory. The wireless network 10 may comprise several such processors distributed within the wireless network 10 and each processor 50, 60 performing one or more steps of the method.

One or more data memories 53, 63 may also be provided for reading and/or storing data during execution of software instructions in the processor(s) 50, 60. The data memory 53, 63 can be any combination of random access memory (RAM) and read only memory (ROM).

The wireless network 10, e.g. network nodes 11, 25 thereof, may comprise a respective input/output device 55, 65 (I/O or IN/OUT) which may comprise an interface for communication exchange with e.g. each other and with other (not illustrated) network nodes. For instance, the serving network node 11 may for instance comprise an X2 interface for communication with a neighboring network node 15.

The wireless network 10, e.g. network nodes 11 thereof providing coverage for UEs, may further comprise or be configured to control a number of antennas, schematically illustrated at reference numeral 54, for providing wireless communication to UEs, in particular by transmitting and/or receiving signaling to/from the UEs within its coverage area(s).

A wireless network 10 is provided for making a handover decision for a communication device 100 served by a network node 11. The network node 11 provides coverage in a serving cell 20 comprising one or more sectors 21, 22, 23. The wireless network 10 is configured to:

- receive, from the communication device 100, a first measurement report relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30,

- configure the communication device 100 to measure on channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30,

- receive, from the communication device 100, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources, and

- make a handover decision based on the received CSI measurement reports.

The wireless network 10 may for example be configured to perform the steps by comprising at least one processor 50, 60 and memory 51, 61 the memory 51, 61 containing instructions executable by the processor 50, 60, whereby the wireless network 10 is operative to perform the steps.

In an embodiment, the wireless network 10 is configured to configure the communication device 100 to measure on channel state information reference signal, CSI-RS, resources used by sectors 21, 22, 23 of the serving cell 20.

In an embodiment, the first measurement report comprises the ratio of reference signal received power, RSRP1, to reference signal received quality, RSRQ1, of reference signals from the serving cell 20 and ratio of reference signal received power, RSRP2, to reference signal received quality, RSRQ2, of reference signals from the neighboring cell 30.

In an embodiment, the wireless network 10 is configured to, prior to the configuring, establish a need for CSI-RS measurements.

In a variation of the above embodiment, the wireless network 10 is configured to establish a need for CSI-RS measurements by establishing that the communication device 100 is approaching a border between the serving cell 20 and the neighboring cell 30.

In an embodiment, the wireless network 10 is configured to make a handover decision by making the handover decision based on comparison of signal strengths of sectors 21, 22, 23 of the serving cell 20 and signal strengths of sectors 31, 32, 33 of the neighboring cell 30.

In an embodiment, the wireless network 10 is configured to, prior to making a handover decision, calculate values of one or more of: uplink path gains of the sectors 21, 22, 23 of the serving cell 20, uplink path gains of the sectors 31, 32, 33 of the neighboring cell 30, per sector filtered CSI measurement reports for sectors 21, 22, 23 of the serving cell 20, and per sector filtered CSI measurement reports for sectors 31, 32, 33 of the neighboring cell 30.

In an embodiment, the wireless network 10 is configured to make a handover decision by using the calculated values for establishing if uplink handover criteria and/or downlink handover criteria are met, and configured to make the handover if the uplink handover criteria and/or downlink handover criteria are met.

In an embodiment, the wireless network 10 is configured to, prior to the receiving the first measurement report from the communication device 100, configure the communication device 100 with a triggering criterion for triggering the communication device 100 to transmit the first measurement report upon fulfilment of the triggering criterion.

The present disclosure also encompasses computer program products 51, 61 comprising a computer program 52, 62 for implementing the methods as described, e.g. with reference to figure 3, and a computer readable means on which the computer programs are stored. The computer program products 51, 61 may be any combination of random access memory (RAM) or read only memory (ROM). The computer program product may also comprise persistent storage, which for example can be any single one or combination of magnetic memory, optical memory or solid state memory.

The computer program product, or the memory, thus comprises instructions executable by the at least one processor 50, 60. Such instructions may be comprised in a computer program, or in one or more software modules or function modules.

Still with reference to figure 4, the memory 51, 61 can be any combination of random access memory (RAM) and read only memory (ROM), Flash memory, magnetic tape, Compact Disc (CD)-ROM, digital versatile disc (DVD), Blueray disc etc. The memory may also comprise persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory or even remotely mounted memory.

An example of an implementation using functions modules/software modules is illustrated in figure 5, in particular illustrating wireless network 10 comprising function modules for implementing methods of the present disclosure. The wireless network 10 comprises first means 72 for receiving, from the communication device 100, a first measurement report relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30. Such means may comprise processing circuitry, adapted to receive measurement reports via antenna(s) and processing circuitry for receiving signaling.

The wireless network 10 comprises second means 74 for configuring the communication device 100 to measure on channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30. Such means may comprise various processing circuitry, e.g. processing circuitry, adapted to configure by using program code stored in memory, and/or processing circuitry for transmitting.

The wireless network 10 comprises third means 75 for receiving, from the communication device 100, channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources. Such means may comprise processing circuitry, adapted to receive measurement reports via antenna(s) and processing circuitry for receiving signaling.

The wireless network 10 comprises fourth means 77 for making a handover decision based on the received CSI measurement reports. Such means may comprise processing circuitry, adapted to do make a handover decision using program code stored in memory.

The wireless network 10 may comprise additional means for performing any of the various steps of the various embodiments as have been described. For instance, the wireless network 10 may comprise means 71 for configuring the communication device 100 with triggering criterion for triggering transmission of first measurement report. Such means may comprise various processing circuitry, e.g. processing circuitry, adapted to configure by using program code stored in memory, and/or processing circuitry for transmitting.

The wireless network 10 may comprise means 73 for establishing a need for CSI-RS measurement(s). Such means may comprise processing circuitry, adapted to do this establishing using program code stored in memory.

The wireless network 10 may comprise means 76 for calculating one or more of: uplink path gains of the sectors 21, 22, 23 of the serving cell 20, uplink path gains of the sectors 31, 32, 33 of the neighboring cell 30, per sector filtered CSI measurement reports for sectors 21, 22, 23 of the serving cell 20, and per sector filtered CSI measurement reports for sectors 31, 32, 33 of the neighboring cell 30. Such means may comprise processing circuitry, adapted to calculate using program code stored in memory.

The function modules 71, 72, 73, 74, 75, 76, 77 may thus be implemented using software instructions such as computer program executing in a processor and/or using hardware, such as application specific integrated circuits, field programmable gate arrays, discrete logical components etc.

Figure 6 illustrates a flow chart over steps of a method in a network node 11 in accordance with the present disclosure. The box drawn with dashed lines indicates an optional step. The method 80 may be performed in a network node 11 for effectuating a handover decision for a communication device 100 served by the network node 11. The network node 11 provides coverage in a serving cell 20 comprising one or more sectors 21, 22, 23. The method 80 comprises receiving 81 a first measurement report from the communication device 100 relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30.

The method 80 comprises receiving 83 from the communication device 100 channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30.

The method 80 comprises effectuating 84 a handover decision based on the received CSI measurement reports. The handover decision may, but need not, be made by the network node 11. The network node 11 may receive instructions from a central node 25 to effectuate the handover decision by transmitting a handover command message, but wherein the handover decision has been made by the central node 25 based on the received CSI measurement reports, which have been forwarded by to it by the network node 11.

In an embodiment, the method 80 comprises, prior to the receiving from the communication device 100 channel state information measurement reports, transmitting 82 to the communication device 100 a configuration message comprising a configuration of channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30, on which to measure.

In an embodiment, the configuration message further comprises a configuration of channel state information reference signal, CSI-RS, resources used by sectors 21, 22, 23 of the serving cell 20, on which to measure.

In an embodiment, the effectuating 83 the handover decision comprises sending a handover command message to the communication device 100.

In an embodiment, the effectuating 83 the handover decision comprises making the handover decision based on comparison of signal strengths of sectors 21, 22, 23 of the serving cell 20 and signal strengths of sectors 31, 32, 33 of the neighboring cell 30.

With reference again to figure 4, the present disclosure also provides a network node 11 for effectuating a handover decision for a communication device 100 served by the network node 11. The network node 11 comprises means as described in relation to figure 4, e.g. processor 50, input/output 55 etc., and a description of these means and device will not be repeated here.

The network node 11 provides coverage in a serving cell 20 comprising one or more sectors 21, 22, 23. The network node 11 is configured to:

- receive a first measurement report from the communication device 100 relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30,

- receive from the communication device 100 channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30, and

- effectuate a handover decision based on the received CSI measurement reports.

In an embodiment, the network node 11 is configured to, prior to the receiving from the communication device 100 channel state information measurement reports, transmit to the communication device 100 a configuration message comprising a configuration of channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30, on which to measure.

In an embodiment, the configuration message further comprises a configuration of channel state information reference signal, CSI-RS, resources used by sectors 21, 22, 23 of the serving cell 20, on which to measure.

In an embodiment, the network node 11 is configured to effectuate the handover decision by sending a handover command message to the communication device 100. The network node 11 may receive, from a central node 25, instructions to send such handover command message to the communication device 100. The central node 25 may thus be the one making the handover decision, while the network node 11, e.g. the serving network node 11, effectuates the handover decision in that it sends the handover command.

In an embodiment, the network node 11 is configured to effectuate the handover decision by making the handover decision based on comparison of signal strengths of sectors 21, 22, 23 of the serving cell 20 and signal strengths of sectors 31, 32, 33 of the neighboring cell 30.

With reference still to figure 4, the present disclosure further encompasses a computer program 92 for a network node 11 for effectuating a handover decision for a communication device 100 served by the network node 11, wherein the network node 11 provides coverage in a serving cell 20 comprising one or more sectors 21, 22, 23. The computer program 92 comprises computer program code, which, when executed on a processor 50 of the network node 11 causes the network node 11 to perform the method 80 as described for instance in relation to figure 6.

A computer program product 91 is also provided comprising a computer program 92 as described above and a computer readable means on which the computer program 92 is stored.

An example of an implementation using functions modules/software modules is illustrated in figure 7, in particular illustrating network node 11 comprising function modules for implementing methods of the present disclosure. The network node 11 comprises first means 93 for receiving a first measurement report from the communication device 100 relating to channel conditions towards the serving cell 20 and/or towards a neighboring cell 30. Such means may comprise processing circuitry, adapted to receive measurement reports via antenna(s) and processing circuitry for receiving signaling.

The network node 11 comprises second means 95 for receiving from the communication device 100 channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30. Such means may comprise processing circuitry, adapted to receive measurement reports via antenna(s) and processing circuitry for receiving signaling.

The network node 11 comprises third means 96 for effectuating a handover decision based on the received CSI measurement reports. Such means may comprise processing circuitry, adapted to effectuate a handover decision using program code stored in memory and/or processing circuitry for transmitting handover commands.

The network node 11 may comprise additional means for performing any of the various steps of the various embodiments as have been described. For instance, the network node 11 may comprise means 94 for transmitting to the communication device 100 a configuration message comprising a configuration of channel state information reference signal, CSI-RS, resources used by sectors 31, 32, 33 of the neighboring cell 30, on which to measure. Such means may comprise processing circuitry, adapted to transmit configuration messages via antenna(s) and processing circuitry for transmitting signaling.

The function modules 93, 94, 95, 96 may thus be implemented using software instructions such as computer program executing in a processor and/or using hardware, such as application specific integrated circuits, field programmable gate arrays, discrete logical components etc.

It is noted that the measurement reports may also be used in other algorithms, e.g. in order to control PCell handover decisions, selection of sectors used for transmission to the UE after initial setup, setup of new sectors to be used for transmission to the

UE, removal of sectors that are not to be used for transmission to the UE, etc. The network node receiving the measurement reports (typically the serving node) may forward the measurement reports as needed. A node receiving the measurement reports, e.g. a target network node, may thereby e.g. be alleviated from performing measurements on e.g. PRACH.

The invention has mainly been described herein with reference to a few embodiments. However, as is appreciated by a person skilled in the art, other embodiments than the particular ones disclosed herein are equally possible within the scope of the invention, as defined by the appended patent claims.

Claims

1. A method (40) performed in a wireless network (10) for making a handover decision for a communication device (100) served by a network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23), the method (40) comprising:

- receiving (42), from the communication device (100), a first measurement report relating to channel conditions towards the serving cell (20) and/or towards a neighboring cell (30),

- configuring (44) the communication device (100) to measure on channel state information reference signal, CSI-RS, resources used by sectors (31, 32, 33) of the neighboring cell (30),

- receiving (45), from the communication device (100), channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources, and

- making (47) a handover decision based on the received CSI measurement reports.

2. The method (40) as claimed in claim 1, wherein the configuring (44) further comprises configuring the communication device (100) to measure on channel state information reference signal, CSI-RS, resources used by sectors (21, 22, 23) of the serving cell (20).

3. The method (40) as claimed in claim 1 or 2, wherein the first measurement report comprises the ratio of reference signal received power, RSRP1, to reference signal received quality, RSRQ1, of reference signals from the serving cell (20) and ratio of reference signal received power, RSRP2, to reference signal received quality, RSRQ2, of reference signals from the neighboring cell (30).

4. The method (40) as claimed in claim 1, 2 or 3, comprising, prior to the configuring (44), establishing (43) a need for CSI-RS measurements.

5. The method (40) as claimed in claim 4, wherein the establishing (43) a need for CSI-RS measurements comprises establishing that the communication device (100) is approaching a border between the serving cell (20) and the neighboring cell (30).

6. The method (40) as claimed in any of the preceding claims, wherein the making (47) a handover decision comprises making the handover decision based on comparison of signal strengths of sectors (21, 22, 23) of the serving cell (20) and signal strengths of sectors (31, 32, 33) of the neighboring cell (30).

7. The method (40) as claimed in any of the preceding claims, comprising, prior to the making (47) a handover decision, calculating (46) values of one or more of: uplink path gains of the sectors (21, 22, 23) of the serving cell (20), uplink path gains of the sectors (31, 32, 33) of the neighboring cell (30), per sector filtered CSI measurement reports for sectors (21, 22, 23) of the serving cell (20), and per sector filtered CSI measurement reports for sectors (31, 32, 33) of the neighboring cell (30).

8. The method (40) as claimed in claim 7, wherein the making (47) a handover decision comprises using the calculated values for establishing if uplink handover criteria and/or downlink handover criteria are met, and making the handover if the uplink handover criteria and/or downlink handover criteria are met.

9. The method (40) as claimed in any of the preceding claims, comprising, prior to the receiving (42) the first measurement report from the communication device (100), configuring (41) the communication device (100) with a triggering criterion for triggering the communication device (100) to transmit the first measurement report upon fulfilment of the triggering criterion.

10. The method (40) as claimed in any of the preceding claims, performed in a network node (11) of the wireless network (10).

11. The method (40) as claimed in any of claims 1-10, wherein the receiving (42) from the communication device (100), a first measurement report, and the receiving (45), from the communication device (100), channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources, are performed in the serving network node (11), and wherein the configuring (44) the communication device (100) to measure on channel state information reference signal, CSI-RS, resources and making (47) the handover decision are made in a central node (25).

12. A wireless network (10) for making a handover decision for a communication device (100) served by a network node (11), the network node (11) providing coverage

in a serving cell (20) comprising one or more sectors (21, 22, 23), the wireless network (10) being configured to:

- receive, from the communication device (100), a first measurement report relating to channel conditions towards the serving cell (20) and/or towards a neighboring cell (30),

- configure the communication device (100) to measure on channel state information reference signal, CSI-RS, resources used by sectors (31, 32, 33) of the neighboring cell (30),

- receive, from the communication device (100), channel state information, CSI, measurement reports based on measurements on the configured CSI-RS resources, and

- make a handover decision based on the received CSI measurement reports.

13. The wireless network (10) as claimed in claim 12, further configured to configure the communication device (100) to measure on channel state information reference signal, CSI-RS, resources used by sectors (21, 22, 23) of the serving cell (20).

14. The wireless network (10) as claimed in claim 12 or 13, wherein the first measurement report comprises the ratio of reference signal received power, RSRP1, to reference signal received quality, RSRQ1, of reference signals from the serving cell (20) and ratio of reference signal received power, RSRP2, to reference signal received quality, RSRQ2, of reference signals from the neighboring cell (30).

15. The wireless network (10) as claimed in claim 12, 13 or 14, configured to, prior to the configuring, establish a need for CSI-RS measurements.

16. The wireless network (10) as claimed in claim 15, configured to establish a need for CSI-RS measurements by establishing that the communication device (100) is approaching a border between the serving cell (20) and the neighboring cell (30).

17. The wireless network (10) as claimed in any of claims 12-16, configured to make a handover decision by making the handover decision based on comparison of signal strengths of sectors (21, 22, 23) of the serving cell (20) and signal strengths of sectors (31, 32, 33) of the neighboring cell (30).

18. The wireless network (10) as claimed in any of claims 12-17, configured to, prior to making a handover decision, calculate values of one or more of: uplink path gains of the sectors (21, 22, 23) of the serving cell (20), uplink path gains of the sectors (31, 32, 33) of the neighboring cell (30), per sector filtered CSI measurement reports for sectors (21, 22, 23) of the serving cell (20), and per sector filtered CSI measurement reports for sectors (31, 32, 33) of the neighboring cell (30).

19. The wireless network (10) as claimed in claim 18, configured to make a handover decision by using the calculated values for establishing if uplink handover criteria and/or downlink handover criteria are met, and configured to make the handover if the uplink handover criteria and/or downlink handover criteria are met.

20. The wireless network (10) as claimed in any of claims 12-19, configured to, prior to the receiving the first measurement report from the communication device (100), configure the communication device (100) with a triggering criterion for triggering the communication device (100) to transmit the first measurement report upon fulfilment of the triggering criterion.

21. A computer program (52, 62) for a wireless network (10) for making a handover decision for a communication device (100) served by the network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23), the computer program (52, 62) comprising computer program code, which, when executed on at least one processor (50, 60) of the wireless network (10) causes the wireless network (10) to perform the method (40) according to any one of claims 1-11.

22. A computer program product (51, 61) comprising a computer program (52, 62) as claimed in claim 21 and a computer readable means on which the computer program (52, 62) is stored.

23. A method (80) performed in a network node (11) for effectuating a handover decision for a communication device (100) served by the network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23), the method (80) comprising:

- receiving (81) a first measurement report from the communication device (100) relating to channel conditions towards the serving cell (20) and/or towards a neighboring cell (30),

- receiving (83) from the communication device (100) channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30, and

- effectuating (84) a handover decision based on the received CSI measurement reports.

24. The method (80) as claimed in claim 23, comprising, prior to the receiving from the communication device (100) channel state information measurement reports, transmitting (82) to the communication device (100) a configuration message comprising a configuration of channel state information reference signal, CSI-RS, resources used by sectors (31, 32, 33) of the neighboring cell (30), on which to measure.

25. The method (80) as claimed in claim 23 or 24, wherein the configuration message further comprises a configuration of channel state information reference signal, CSI-RS, resources used by sectors (21, 22, 23) of the serving cell (20), on which to measure.

26. The method (80) as claimed in claim 23, 24 or 25, wherein the effectuating (83) the handover decision comprises sending a handover command message to the communication device (100).

27. The method (80) as claimed in any of claims 23-26, wherein the effectuating (83) the handover decision comprises making the handover decision based on comparison of signal strengths of sectors (21, 22, 23) of the serving cell (20) and signal strengths of sectors (31, 32, 33) of the neighboring cell (30).

28. A network node (11) for effectuating a handover decision for a communication device (100) served by the network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23), the network node (11) being configured to:

- receive a first measurement report from the communication device (100) relating to channel conditions towards the serving cell (20) and/or towards a neighboring cell (30),

- receive from the communication device (100) channel state information, CSI, measurement reports based on measurements on configured CSI-RS resources used by sectors 31, 32, 33 of the neighboring cell 30, and

- effectuate a handover decision based on the received CSI measurement reports.

29. The network node (11) as claimed in claim 28, configured to, prior to the receiving from the communication device (100) channel state information measurement reports, transmit to the communication device (100) a configuration message comprising a configuration of channel state information reference signal, CSI-RS, resources used by sectors (31, 32, 33) of the neighboring cell (30), on which to measure.

30. The network node (11) as claimed in claim 28 or 29, wherein the configuration message further comprises a configuration of channel state information reference signal, CSI-RS, resources used by sectors (21, 22, 23) of the serving cell (20), on which to measure.

31. The network node (11) as claimed in claim 28, 29 or 30, configured to effectuate the handover decision by sending a handover command message to the communication device (100).

32. The network node (11) as claimed in any of claims 28-31, configured to effectuate the handover decision by making the handover decision based on comparison of signal strengths of sectors (21, 22, 23) of the serving cell (20) and signal strengths of sectors (31, 32, 33) of the neighboring cell (30).

33. A computer program (92) for a network node (11) for effectuating a handover decision for a communication device (100) served by the network node (11), the network node (11) providing coverage in a serving cell (20) comprising one or more sectors (21, 22, 23), the computer program (92) comprising computer program code, which, when executed on a processor (50) of the network node (11) causes the network node (11) to perform the method (80) according to any one of claims 23-27.

34. A computer program product (91) comprising a computer program (92) as claimed in claim 33 and a computer readable means on which the computer program (92) is stored.

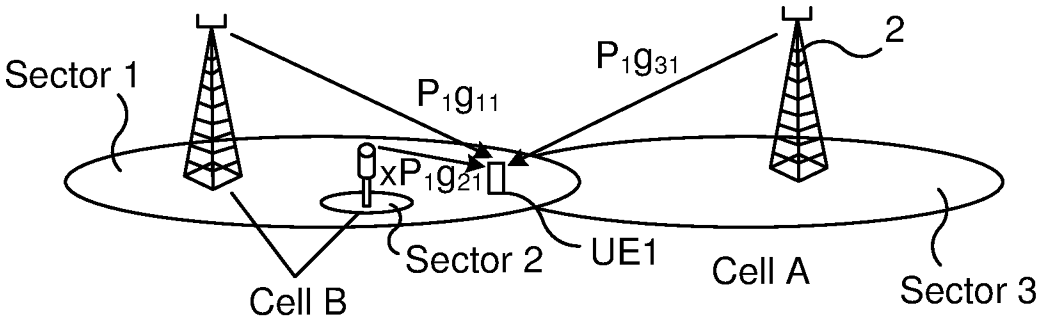
Sector 1
P1g11
P1g31
2
xP1g21
Sector 2
UE1
Cell A
Sector 3
Cell B

Fig. 1

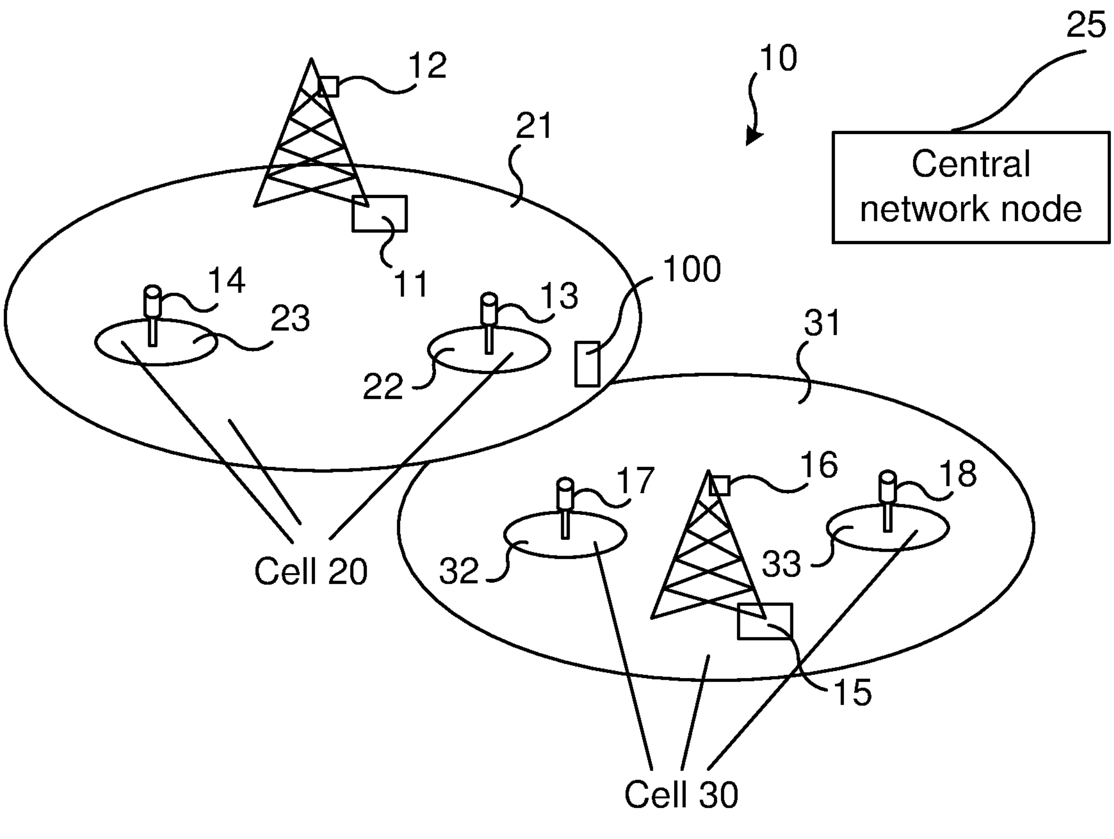
25
10
12
21
Central network node
11
14
23
13
100
22
31
17
16
18
Cell 20
32
33
15
Cell 30

Fig. 2

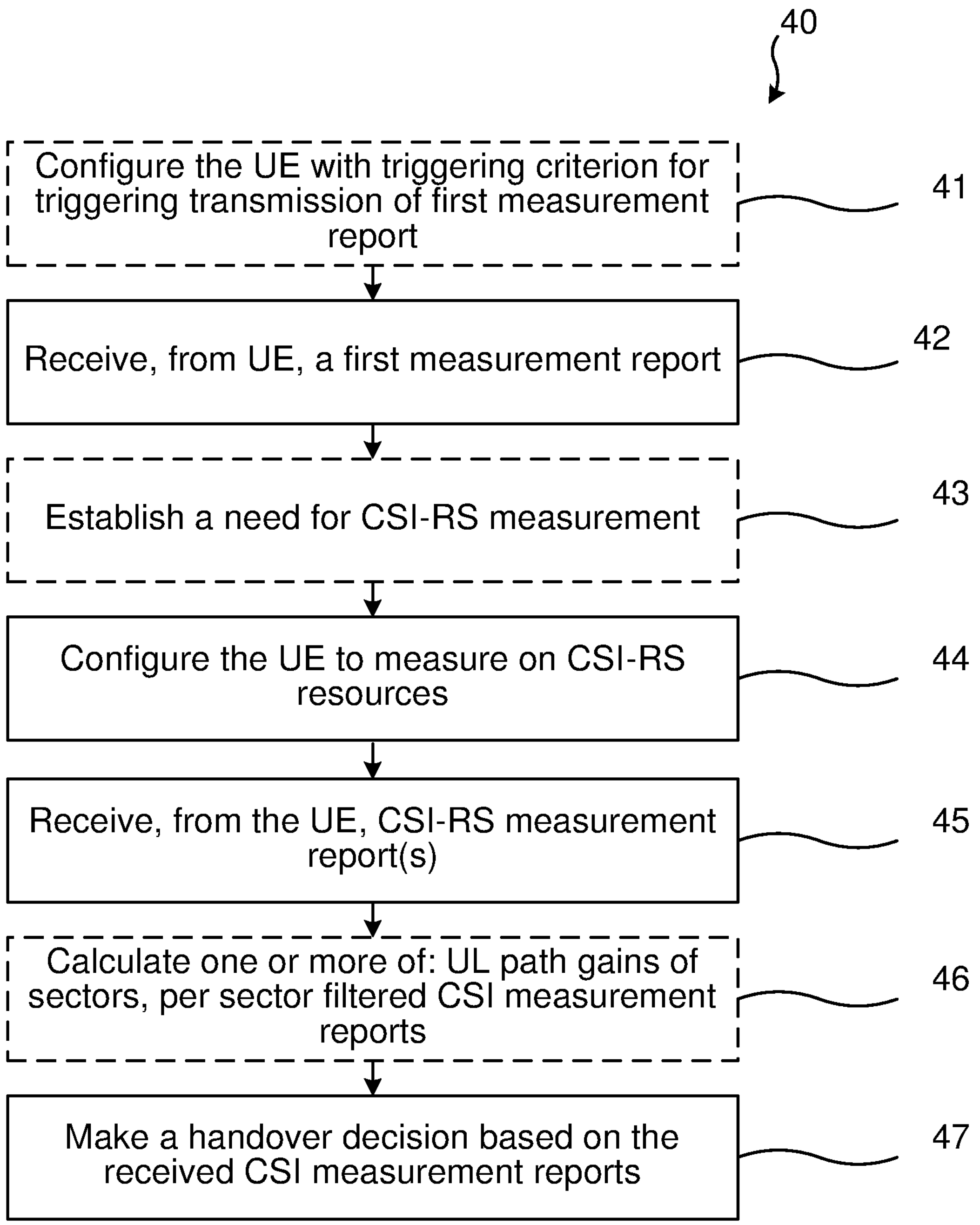
40
Configure the UE with triggering criterion for triggering transmission of first measurement report
41
Receive, from UE, a first measurement report
42
Establish a need for CSI-RS measurement
43
Configure the UE to measure on CSI-RS resources
44
Receive, from the UE, CSI-RS measurement report(s)
45
Calculate one or more of: UL path gains of sectors, per sector filtered CSI measurement reports
46
Make a handover decision based on the received CSI measurement reports
47

Fig. 3

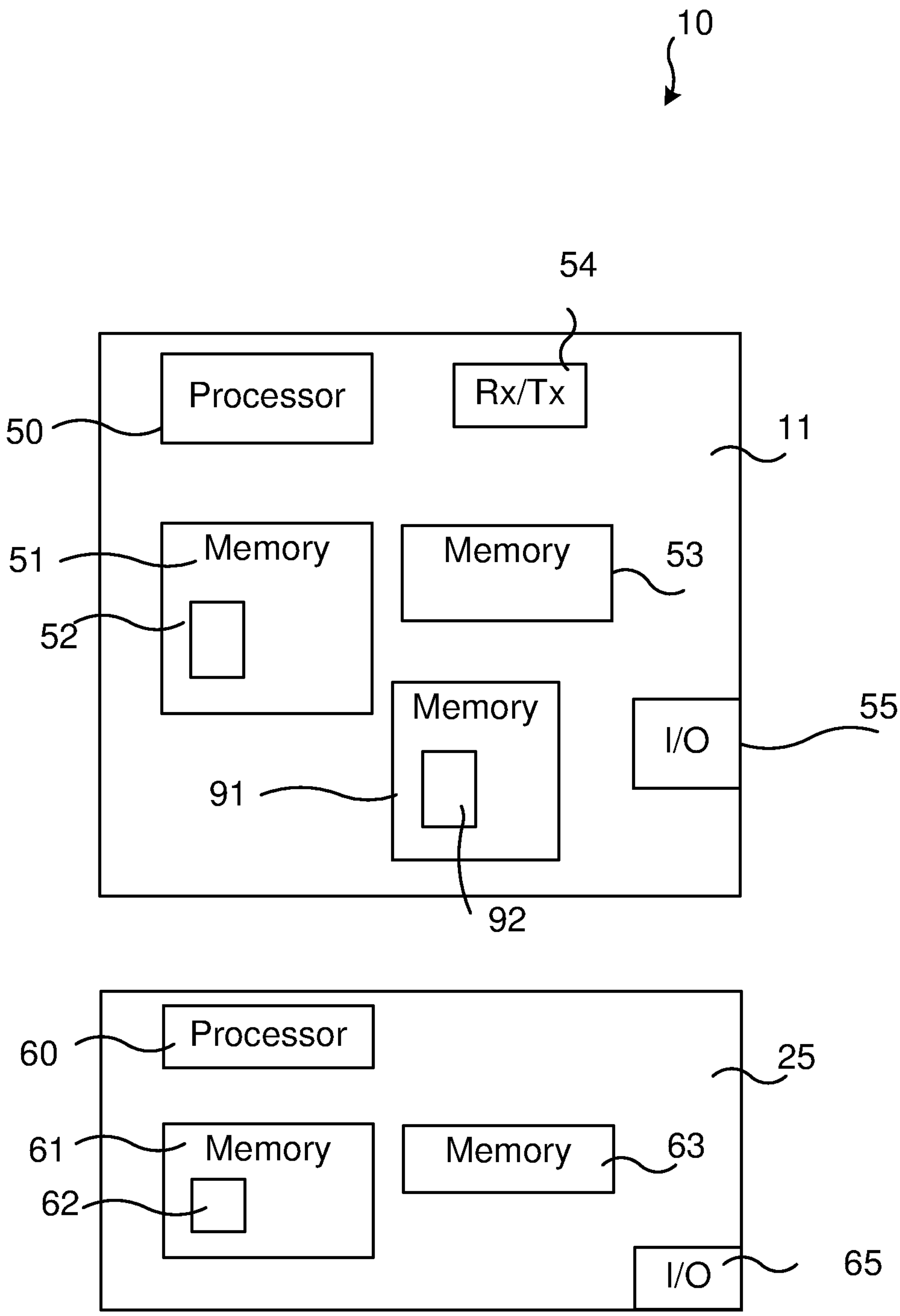
10
54
Processor
Rx/Tx
50
11
51
Memory
Memory
53
52
Memory
I/O
55
91
92
Processor
60
25
61
Memory
Memory
63
62
I/O
65

Fig. 4

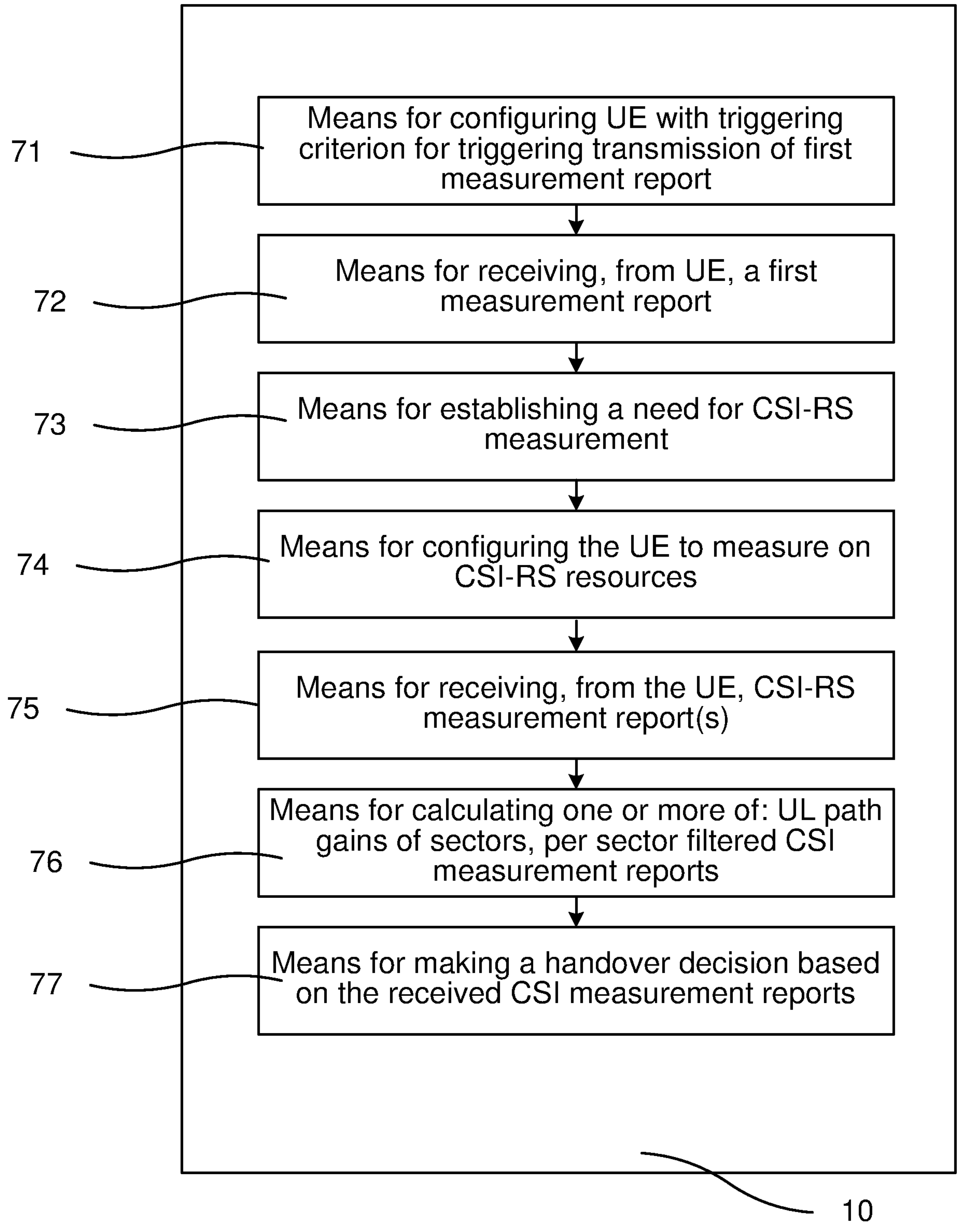
71
Means for configuring UE with triggering criterion for triggering transmission of first measurement report
72
Means for receiving, from UE, a first measurement report
73
Means for establishing a need for CSI-RS measurement
74
Means for configuring the UE to measure on CSI-RS resources
75
Means for receiving, from the UE, CSI-RS measurement report(s)
76
Means for calculating one or more of: UL path gains of sectors, per sector filtered CSI measurement reports
77
Means for making a handover decision based on the received CSI measurement reports
10

Fig. 5

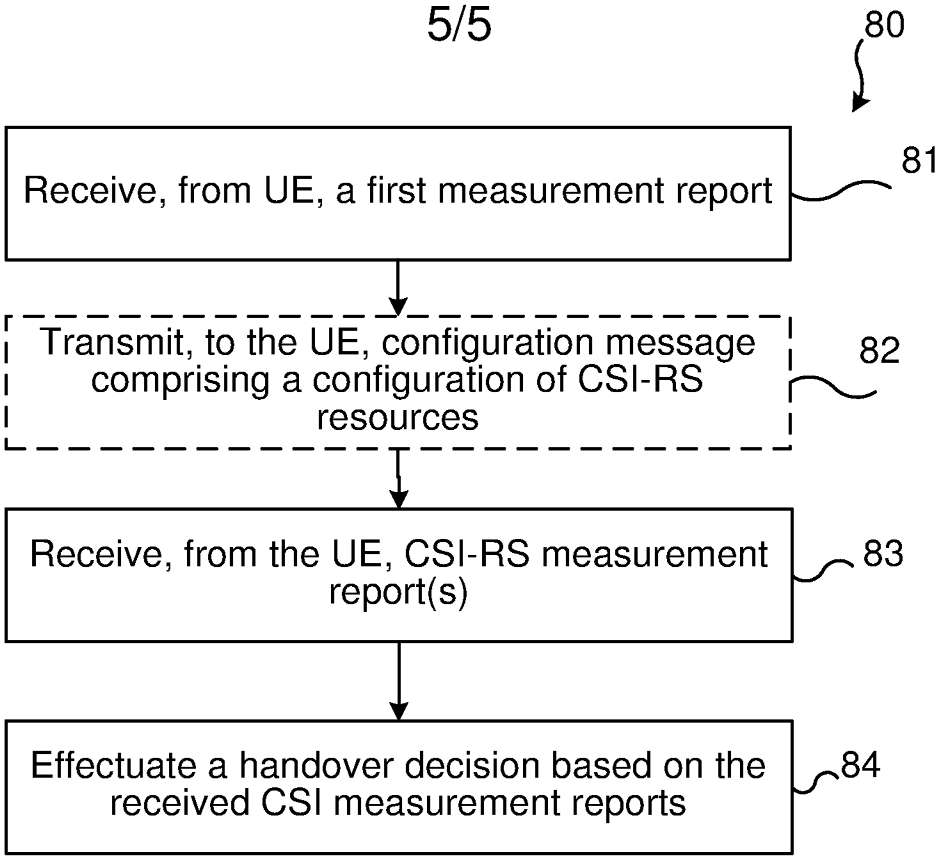
80
Receive, from UE, a first measurement report
81
Transmit, to the UE, configuration message comprising a configuration of CSI-RS resources
82
Receive, from the UE, CSI-RS measurement report(s)
83
Effectuate a handover decision based on the received CSI measurement reports
84

Fig. 6

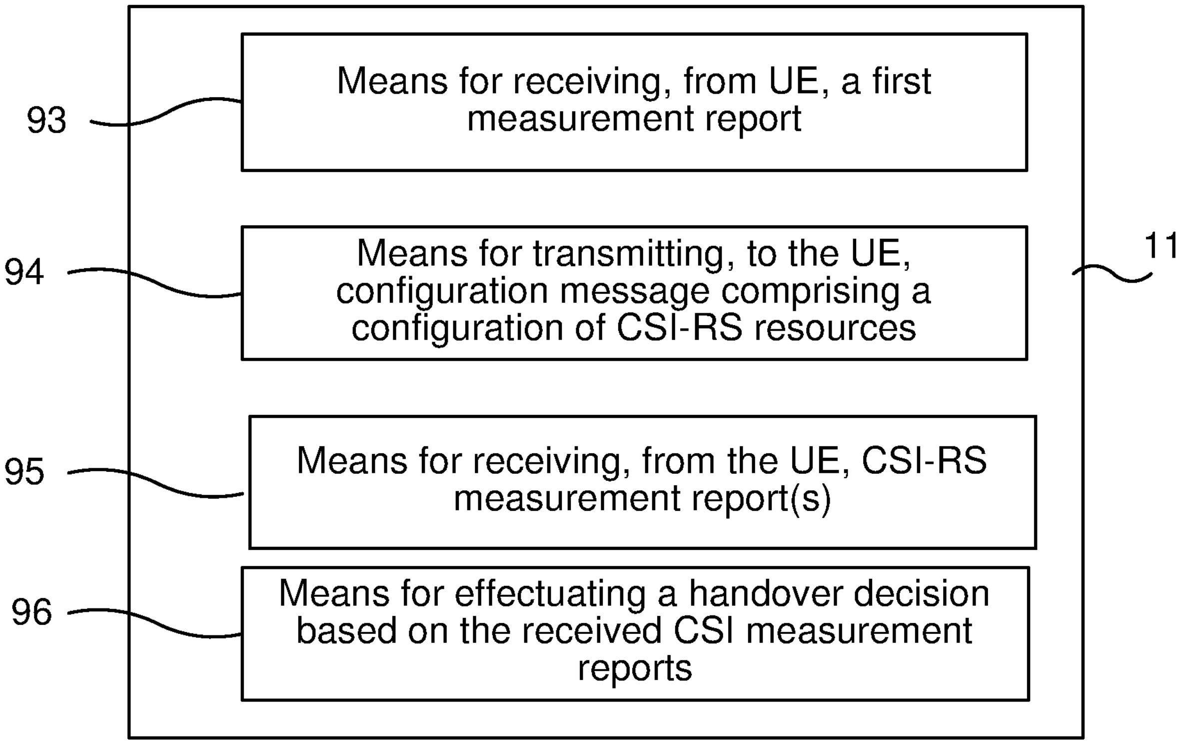
93
Means for receiving, from UE, a first measurement report
94
Means for transmitting, to the UE, configuration message comprising a configuration of CSI-RS resources
95
Means for receiving, from the UE, CSI-RS measurement report(s)
96
Means for effectuating a handover decision based on the received CSI measurement reports
11

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2014/050899

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W36/00
ADD. H04W16/32 H04W24/10

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, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/108807 A1 (ERICSSON TELEFON AB L M [SE]; JOENGREN GEORGE [SE]; LINDBOM LARS [SE];) 16 August 2012 (2012-08-16)	1,2, 4-13, 15-25, 27-30, 32-34
Y	page 5, line 1 - page 6, line 25 page 11, line 3 - line 14 page 12, line 36 - page 14, line 9 page 17, line 8 - page 18, line 17 figure 10 -----	3,14,26, 31

-/--

[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

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"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
10 March 2015	17/03/2015

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	Donnini, Carlo Luca

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INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2014/050899

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	GB 2 507 821 A (SAMSUNG ELECTRONICS CO LTD [KR]) 14 May 2014 (2014-05-14)	26,31
A	page 19, line 5 - page 21, line 27 page 23, line 10 - page 25, line 29 page 26, line 25 - page 27, line 18 page 27, line 29 - page 30, line 25 page 31, line 29 - page 32, line 21 page 33, line 18 - page 35, line 14 -----	1-25, 27-30, 32-34
A	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 11)", 3GPP STANDARD; 3GPP TS 36.213, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE, vol. RAN WG1, no. V11.7.0, 19 June 2014 (2014-06-19), pages 1-182, XP050774080, [retrieved on 2014-06-19] 7.2 UE procedure for reporting Channel State Information (CSI) -----	1-34
A	WO 2012/136450 A1 (NOKIA SIEMENS NETWORKS OY [FI]; HOEHNE HANS THOMAS [FI]; SAYENKO ALEXA) 11 October 2012 (2012-10-11) page 12, line 4 - page 14, line 1 -----	1-34
Y	WO 2013/067934 A1 (MEDIATEK INC [CN]) 16 May 2013 (2013-05-16)	3,14
A	paragraph [0011] paragraph [0042] - paragraph [0044] -----	1,2, 4-13, 15-34
A	EP 2 663 130 A1 (LG ELECTRONICS INC [KR]) 13 November 2013 (2013-11-13) paragraph [0005] - paragraph [0019] paragraph [0054] - paragraph [0055] -----	1-34
A	US 2010/223522 A1 (DUGGAN JASON ROBERT [CA]) 2 September 2010 (2010-09-02) paragraph [0076] - paragraph [0079] -----	1-34

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/SE2014/050899

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			EP 2661923	A1	13-11-2013
			JP 2014530529	A	17-11-2014
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			US 2013279362	A1	24-10-2013
			WO 2012093759	A1	12-07-2012
US 2010223522	A1	02-09-2010	NONE		