When the mobile terminal 92 again moves into the cell formed by the base station 91, the mobile terminal 92 receives, from among notification information transmitted from the base station 91, the SIB1 that contains a cell ID and a "Value tag". Then, the mobile terminal 92 determines whether the cell ID contained in the SIB1 matches the cell ID contained in the notification information retained in the mobile terminal 92. If both cell IDs match, the mobile terminal 92 compares the "Value tag" contained in the SIB1 received from the base station 91 with the "Value tag" of the notification information retained in the mobile terminal 92.

[0012] If the cell IDs differ or if the "Value tags" differ, the mobile terminal 92 receives all the pieces of notification information transmitted from the base station 91. Then, the mobile terminal 92 updates all the pieces of notification information retained in the mobile terminal 92 to the notification information received from the base station 91.

[0013] As described above, when the mobile terminal 92 moves between cells, the mobile terminal 92 may sometimes receive all the pieces of notification information transmitted from the base station 91. Accordingly, as illustrated in the lower portion of FIG. 19 , the mobile terminal 92 consumes received electrical power when it receives the SIB1 to the SIB11. Accordingly, in the mobile terminal 92, the electrical power consumed when the receiving process is performed on the notification information increases. The mobile terminal 92 also receives the SIB1 when the power supply of the mobile terminal 92 is turned on or when the mobile terminal 92 moves into a service range from outside a service range. At this time, if cell IDs or "Value tags" differ, the mobile terminal 92 receives all the pieces of notification information. Accordingly, when the power supply of the mobile terminal 92 is turned on or when the mobile terminal 92 moves into a service range from outside a service range, the electrical power consumed when the receiving process is performed on the notification information also increases.

[0014] Accordingly, the present application has been conceived in light of the circumstances described above, and an object thereof is to provide a wireless communication system, a transmitter, a receiving apparatus, and a notification information transmission-reception method that can reduce electrical power consumed when a receiving process is performed on notification information.

Solution to Problem

[0015] According to an aspect of the embodiments, a wireless communication system includes a transmitter and a receiving apparatus. The transmitter includes a revision history creating unit that creates revision history containing change information related to notification information when the notification information has been changed, and a transmitting unit that transmits notification information containing the revision history created by the revision history creating unit. The receiving apparatus includes a storing unit that stores therein notification information, a receiving unit that receives the revision history from among the notification information transmitted by the transmitting unit, and an updating unit that updates the notification information stored in the storing unit on the basis of change information contained in the revision history received by the receiving unit.

Advantageous Effects of Invention

[0016] According to an aspect of an embodiment, an advantage is provided in that a wireless communication system can reduce electrical power consumed when a receiving process is performed on notification information.

Brief Description of Drawings

[0017]

FIG. 1 is a block diagram illustrating an example configuration of a wireless communication system according to a first embodiment.
FIG. 2 is a schematic diagram illustrating a transmission/receiving process performed on notification information.
FIG. 3 is a schematic diagram illustrating a transmission/receiving process performed on notification information.
FIG. 4 is a block diagram illustrating an configuration example of a base station according to a second embodiment.
FIG. 5 is a schematic diagram illustrating an example of the revision history of notification information created by a revision history creating unit illustrated in FIG. 4 .
FIG. 6 is a block diagram illustrating an example configuration of a mobile terminal according to the second embodiment.
FIG. 7 is a flowchart illustrating the flow of a notification information transmission process performed by the base station according to the second embodiment.
FIG. 8 is a flowchart illustrating the flow of a notification information receiving process performed by the mobile terminal according to the second embodiment.
FIG. 9 is a flowchart illustrating the flow of a notification information receiving process performed when the mobile terminal according to the second embodiment moves between cells.
FIG. 10 is a schematic diagram illustrating an example of a revision history in which a "Value tag" is associated with change information.
FIG. 11 is a schematic diagram illustrating an example of a revision history in which the date and time at which notification information is changed is associated with the change information.
FIG. 12 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information.
FIG. 13 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information.
FIG. 14 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information.
FIG. 15 is a block diagram illustrating a computer that executes a transmission control program.
FIG. 16 is a block diagram illustrating a computer that executes a reception control program.
FIG. 17 is a schematic diagram illustrating an example of notification information transmitted by a conventional base station.
FIG. 18 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information by a conventional base station and a conventional mobile terminal.
FIG. 19 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information by a conventional base station and a conventional mobile terminal.

Embodiment for Carrying Out the Invention

[0018] Preferred embodiments of a wireless communication system, a transmitter, a receiving apparatus, and a notification information transmission-reception method disclosed in the present application will be described in detail below with reference to the accompanying drawings. The wireless communication system, the transmitter, the receiving apparatus, and the notification information transmission-reception method are not limited to these embodiments disclosed in the present application.

[First Embodiment]

[0019] First, a wireless communication system according to a first embodiment will be described with reference to FIG. 1. FIG. 1 is a block diagram illustrating an example configuration of a wireless communication system according to a first embodiment. As illustrated in FIG. 1 , a wireless communication system 1 according to the first embodiment includes a transmitter 10 and a receiving apparatus 20. The transmitter 10 and the receiving apparatus 20 perform wireless communication each other.

[0020] The transmitter 10 is, for example, a base station and includes, as illustrated in FIG. 1 , a revision history creating unit 11 and a transmitting unit 12. If notification information has been changed, the revision history creating unit 11 creates change information related to the notification information as revision history. For example, if the revision history creating unit 11 receives a request to change notification information from, for example, a higher-level device, the revision history creating unit 11 creates revision history of the notification information.

[0021] The "change information related to the notification information" mentioned here indicates, for example, the difference between notification information that has not been changed and notification information that has been changed. For example, it is assumed that a "paging period of "10"" is contained in notification information that has not been changed and assumed that a "paging period of "8"" is contained in notification information that has been changed. In such a case, the "change information related to the notification information" indicates the "paging period of "8"". Then, the change information related to such notification information is set as history in the "revision history of the notification information".

[0022] The transmitting unit 12 transmits notification information containing the revision history created by the revision history creating unit 11. For example, in addition to the regularly transmitted notification information, the transmitting unit 12 transmits, as notification information, revision history created by the revision history creating unit 11.

[0023] The receiving apparatus 20 is, for example, a mobile terminal and includes, as illustrated in FIG. 1 , a storing unit 21, a receiving unit 22, and an updating unit 23. The storing unit 21 stores therein notification information. The receiving unit 22 receives revision history from among notification information transmitted by the transmitting unit 12 in the transmitter 10. On the basis of the revision history of the notification information received by the receiving unit 22, the updating unit 23 updates the notification information stored in the storing unit 21.

[0024] As described above, in the wireless communication system 1 according to the first embodiment, the transmitter 10 transmits notification information containing revision history. Instead of receiving all the pieces of notification information, the receiving apparatus 20 receives the revision history of the notification information and updates, on the basis of the received revision history, notification information that is retained in the receiving apparatus 20.

[0025] Accordingly, with the receiving apparatus 20 according to the first embodiment, even when notification information has been changed or even when the receiving apparatus 20 has moved between cells, the receiving apparatus 20 receives only revision history instead of receiving all the pieces of notification information. Consequently, the receiving apparatus 20 can reduce electrical power consumed when a receiving process is performed on the notification information. Furthermore, because the receiving apparatus 20 updates only the changed notification information, the receiving apparatus 20 can reduce electrical power consumed when an update process is performed on the notification information.

[Second Embodiment]

[0026] In the following, in a second embodiment, a description will be given of a case in which the transmitter 10 described in the first embodiment is used for a base station and the receiving apparatus 20 is used for a mobile terminal.

[0027] Notification information transmission process performed by the wireless communication system according to the second embodiment

[0028] First, a notification information transmission process in a wireless communication system according to the second embodiment will be described with reference to FIGS. 2 and 3 . FIGS. 2 and 3 are schematic diagrams each illustrating a transmission/receiving process performed on notification information. As illustrated in FIG. 2 , a wireless communication system 2 according to the second embodiment includes a base station 100 and a mobile terminal 200.

[0029] Similarly to the example illustrated in FIG. 18 , the base station 100 according to the second embodiment regularly transmits the SIB1 to the SIB11 as notification information. Furthermore, the base station 100 creates the SIB12 that contains revision history of change information that is the contents of the changed notification information from among the SIB1 to the SIB11 and also regularly transmits the created SIB12. In other words, the base station 100 transmits, as notification information, the SIB1 to the SIB11 and the SIB12 that indicates revision history of the notification information.

[0030] At this stage, it is assumed that the notification information contained in the SIB2 has been changed. In such a case, the base station 100 creates the SIB12 that contains change information on the SIB2. For example, it is assumed that the SIB2 contains information on a paging period and assumed that the paging period has been changed from "10" to "8". In such a case, the base station 100 updates the contents of the SIB2 to the "paging period of "8"" and creates the SIB12 containing the "paging period of "8"". Then, the base station 100 transmits notification information containing the changed SIB2 and the SIB12. Furthermore, the base station 100 transmits paging to notify the mobile terminal 200 that the notification information has been changed.

[0031] If the mobile terminal 200 according to the second embodiment receives the paging from the base station 100, the mobile terminal 200 determines whether the paging indicates a call. If the paging does not indicate a call, the mobile terminal 200 determines that notification information has been changed. Then, as in the example illustrated in FIG. 2 , the mobile terminal 200 receives the SIB12 that contains the revision history of the notification information from among the notification information transmitted from the base station 100. Then, on the basis of the change information contained in the revision history in the SIB12, the mobile terminal 200 updates the notification information that is retained in the mobile terminal 200. For example, as in the example described above, if the "paging period of "8"" is contained in the SIB12, the mobile terminal 200 updates the paging period retained in the mobile terminal 200 to "8".

[0032] As described above, if notification information has been changed, the base station 100 transmits an SIB containing revision history of the notification information. Then, if the mobile terminal 200 detects that the notification information has been changed, the mobile terminal 200 updates the notification information by receiving, from among notification information transmitted from the base station 100, the SIB containing the revision history of the notification information. Accordingly, because the base station 100 receives only an SIB that contains revision history even when the notification information has been changed, the base station 100 can reduce electrical power consumed when the receiving process is performed on the notification information and also reduce electrical power consumed when the update process is performed on the notification information.

[0033] In the following, similarly to the example illustrated in FIG. 2 , the base station 100 in the example illustrated in FIG. 3 regularly transmits the SIB1 to the SIB12. In this example, which is similar to the example illustrated in FIG. 2 , it is assumed that the notification information contained in the SIB2 has been changed. Furthermore, it is assumed that a cell ID and a "Value tag" are contained in the SIB1.

[0034] It is assumed that the mobile terminal 200 illustrated in FIG. 3 moves from a cell formed by the base station 100 to another cell and then again moves into the cell formed by the base station 100. Furthermore, it is assumed that, even after the mobile terminal 200 has moved to the other cell, the mobile terminal 200 still retains the notification information that is received from the base station 100 when the mobile terminal 200 is located in the cell formed by the base station 100.

[0035] In such a case, from among the notification information transmitted from the base station 100, the mobile terminal 200 receives the SIB1 that contains a "Value tag". Then, from among the notification information retained in the mobile terminal 200, the mobile terminal 200 determines whether notification infomation containing a cell ID that matches the cell ID contained in the SIB1 is present. If the notification information containing the cell ID that matches the cell ID contained in the SIB1 is present, the mobile terminal 200 determines whether the "Value tag" of the notification information matches the "Value tag" contained in the SIB1.

[0036] In this example, it is assumed that the mobile terminal 200 retains notification information, which contains a cell ID that matches the cell ID contained in the SIB1 but contains a "Value tag" that does not match the "Value tag" contained in the SIB1. In such a case, as in the example illustrated FIG. 3 , the mobile terminal 200 receives the SIB12 containing the revision history of the notification information. Then, on the basis of the change information contained in the revision history in the SIB12, the mobile terminal 200 updates the notification information that is retained in the mobile terminal 200.

[0037] As described above, when the mobile terminal 200 moves between cells, first, the mobile terminal 200 receives an SIB that contains a "Value tag" from among the notification information transmitted from the base station 100 and then determines whether the "Value tag" matches that in the notification information retained in the mobile terminal 200. Then, if the mobile terminal 200 retains the notification information that contains a matched cell ID but contains a "Value tag" that does not match, the mobile terminal 200 updates the notification information by receiving the SIB containing the revision history of the notification information. Accordingly, because the mobile terminal 200 receives only an SIB that contains the revision history even when the mobile terminal 200 moves between cells, the mobile terminal 200 can reduce electrical power consumed when the receiving process is performed on the notification information and also reduce electrical power consumed when the update process is performed on the notification information.

[0038] In the example illustrated in FIGS. 2 and 3 , a description has been given of an example in which the base station 100 transmits the SIB1 to the SIB11 containing the notification information and transmits the SIB12 containing the revision history of the notification information. However, the number of SIBs transmitted by the base station 100 is not limited to the example illustrated in FIGS. 2 and 3 . For example, when the base station 100 transmits the SIB1 to an SIB15 containing notification information, the base station 100 may also transmit, in addition to the SIB1 to the SIB15, an SIB16 that contains the revision history of the notification information. In such a case, the mobile terminal 200 acquires the revision history of the notification information by receiving the SIB16.

[0039] Furthermore, in the example illustrated in FIGS. 2 and 3 , a description has been given of an example in which revision history of notification information is contained in the single SIB12. However, the base station 100 may also transmit multiple SIBs containing the revision history of the notification information. For example, when the base station 100 transmits the SIB1 to the SIB15 containing notification information, in addition to the SIB1 to the SIB15, the base station 100 may also transmit the SIB16 and an SIB17 containing revision history of notification information. In such a case, the mobile terminal 200 acquires the revision history of the notification information by receiving the SIB16 and the SIB17.

Configuration of the base station according to the second embodiment

[0040] In the following, the configuration of the base station 100 according to the second embodiment will be described with reference to FIG. 4. FIG. 4 is a block diagram illustrating an configuration example of the base station 100 according to a second embodiment. Furthermore, FIG. 4 illustrates units related to the notification information transmission process performed by the base station 100.

[0041] As illustrated in FIG. 4 , the base station 100 according to the second embodiment includes a paging creating unit 101, an encoding unit 102, a modulating unit 103, a notification information creating unit 104, a revision history creating unit 105, and a notification information buffer 106.

[0042] The paging creating unit 101 creates paging information to be transmitted to the mobile terminal 200. For example, the paging creating unit 101 creates paging information when it receives a call request from, for example, a higher-level device. Furthermore, for example, the paging creating unit 101 creates paging information when it receives a notification indicating that notification information has been changed from the notification information creating unit 104, which will be described later.

[0043] The encoding unit 102 encodes the paging information created by the paging creating unit 101. The modulating unit 103 modulates the paging information encoded by the encoding unit 102. Then, the modulating unit 103 outputs the modulated paging information to a radio transmitting unit 110. Accordingly, the paging information is transmitted to an external source via the radio transmitting unit 110 and an antenna 111.

[0044] The notification information creating unit 104 creates notification information. Specifically, if the notification information creating unit 104 receives a request to change the notification information from, for example, a higher-level device, the notification information creating unit 104 creates notification information on the basis of the change request. At this time, the notification information creating unit 104 increments the current "Value tag" and creates notification information containing the incremented "Value tag". Furthermore, the notification information creating unit 104 outputs the change information related to the notification information to the revision history creating unit 105. Accordingly, revision history of the notification information is created by the revision history creating unit 105. Then, the notification information creating unit 104 stores, in the notification information buffer 106, both the notification information created by the notification information creating unit 104 and the revision history of the notification information created by the revision history creating unit 105.

[0045] Furthermore, the notification information creating unit 104 notifies the paging creating unit 101 that the notification information has been changed. Accordingly, if the notification information has been changed, the paging creating unit 101 can create paging information and transmit the paging information to the cell formed by the base station 100.

[0046] The revision history creating unit 105 creates revision history of notification information on the basis of the change information related to the notification information that is received from the notification information creating unit 104. Then, the revision history creating unit 105 outputs the created revision history of the notification information to the notification information creating unit 104.

[0047] The notification information buffer 106 stores therein notification information. If the notification information stored in the notification information buffer 106 is changed, the notification information is updated by the notification information creating unit 104.

[0048] The notification information creating unit 104, the revision history creating unit 105, and the notification information buffer 106 will be described using the example illustrated in FIG. 2 . The notification information buffer 106 stores therein the SIB1 to the SIB12 as notification information. If the notification information creating unit 104 receives, from a higher-level device, a request to change the notification information contained in the SIB2, the notification information creating unit 104 creates the SIB2 in accordance with the change request and outputs the change information related to the notification information to the revision history creating unit 105. On the basis of the change information related to the notification information received from the notification information creating unit 104, the revision history creating unit 105 creates the SIB12 containing the revision history of the notification information and outputs the created SIB12 to the notification information creating unit 104. Then, the notification information creating unit 104 updates the SIB2 and the SIB12 stored in the notification information buffer 106 to the SIB2 that is created by the notification information creating unit 104 and the SIB12 that is received from the revision history creating unit 105. If the notification information creating unit 104 changes the notification information contained in the SIB1 by incrementing the "Value tag", the notification information creating unit 104 updates the SIB1 stored in the notification information buffer 106 to the SIB1 in which the "Value tag" is incremented.

[0049] As illustrated in FIG. 4 , the base station 100 includes a transmission timing control unit 107, an encoding unit 108, a modulating unit 109, the radio transmitting unit 110, and the antenna 111. The transmission timing control unit 107 controls the transmission timing of the notification information. For example, the transmission timing control unit 107 instructs the notification information buffer 106 to output notification information to the encoding unit 108 at 720-ms intervals.

[0050] The encoding unit 108 encodes the notification information that is output from the notification information buffer 106. The modulating unit 109 modulates the notification information that is encoded by the encoding unit 108. The radio transmitting unit 110 transmits the paging information that is input from the modulating unit 103 or the notification information that is input from the modulating unit 109 to an external source via the antenna 111.

[0051] In the following, the revision history of the notification information created by the revision history creating unit 105 illustrated in FIG. 4 will be described with reference to FIG. 5. FIG. 5 is a schematic diagram illustrating an example of the revision history of notification information created by the revision history creating unit 105 illustrated in FIG. 4 .

[0052] In the example illustrated in FIG. 5 , the revision history creating unit 105 creates the revision history of the notification information in the order of revision history R11, revision history R12 and revision history R13. Specifically, it is assumed that, first, the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "received electrical power corresponding to the condition for moving into a cell ID of "XXX" is changed to "3 dB". In such a case, the revision history creating unit 105 creates the revision history R11 as illustrated in FIG. 5 .

[0053] Thereafter, for example, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "the cell ID of "YYY" is deleted from a peripheral cell list" and the change information indicating that "the cell ID of "ZZZ" is deleted from the peripheral cell list". In such a case, as in the example illustrated in FIG. 5 , the revision history creating unit 105 creates the revision history R12 in which new change information is added to the revision history R11.

[0054] Thereafter, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "the paging period is changed to "8"". In such a case, as in the example illustrated in FIG. 5 , the revision history creating unit 105 creates revision history R13 in which a new change is added to the revision history R12.

[0055] As described above, the revision history creating unit 105 creates revision history of the notification information every time the revision history creating unit 105 is notified by the notification information creating unit 104 of the change information related to the notification information. The revision history creating unit 105 may also regularly delete the change information contained in the revision history of the notification information. For example, the revision history creating unit 105 may also delete change information when a predetermined time has elapsed after a new change is added to the revision history of the notification information. Furthermore, for example, if the amount of information that can be set in an SIB is exceeded, the revision history creating unit 105 may also delete change information in its chronological order.

Configuration of the mobile terminal according to the second embodiment

[0056] In the following, the configuration of the mobile terminal 200 according to the second embodiment will be described with reference to FIG. 6. FIG. 6 is a block diagram illustrating an example configuration of the mobile terminal 200 according to the second embodiment. Furthermore, FIG. 6 illustrates units related to the notification information receiving process performed by the mobile terminal 200.

[0057] As illustrated in FIG. 6 , the mobile terminal 200 according to the second embodiment includes an antenna 201, a radio receiving unit 202, a demodulating unit 203, a decoding unit 204, a notification information buffer 205, a notification information processing unit 206, a paging processing unit 207, and a reception timing control unit 208.

[0058] The antenna 201 receives a signal from an external source. For example, the antenna 201 receives paging information and notification information from the base station 100. The radio receiving unit 202 receives various signals from an external source via the antenna 201. The process performed by the radio receiving unit 202 will be described later together with the process performed by the reception timing control unit 208.

[0059] The demodulating unit 203 demodulates the paging information and the notification information received by the radio receiving unit 202. The decoding unit 204 decodes the paging information or the notification information demodulated by the demodulating unit 203. If the decoding unit 204 decodes the paging information, the decoding unit 204 outputs the decoded paging information to the paging processing unit 207. Furthermore, if the decoding unit 204 decodes the notification information, the decoding unit 204 outputs the decoded notification information to the notification information processing unit 206.

[0060] The notification information buffer 205 stores therein the notification information. Furthermore, the notification information buffer 205 stores therein multiple pieces of notification information. For example, it is assumed that the mobile terminal 200 moves from cell A to cell B. In such a case the notification information buffer 205 stores therein the notification information received from the base station in cell B that is the move destination and also stores therein the notification information received from the base station by the mobile terminal 200 in cell A.

[0061] The notification information processing unit 206 performs, for example, the update process on notification information by using notification information decoded by the decoding unit 204. Specifically, if an SIB containing revision history of notification information is input from the decoding unit 204, the notification information processing unit 206 stores, in the notification information buffer 205, the change information contained in the revision history of the notification information.

[0062] For example, in the example illustrated in FIG. 2 , the notification information processing unit 206 receives an input of the SIB12 from the decoding unit 204. In such a case, the notification information processing unit 206 stores, in the notification information buffer 205, the change information contained in the revision history in the SIB12.

[0063] Furthermore, if an SIB containing a cell ID or a "Value tag" is input from the decoding unit 204, the notification information processing unit 206 determines whether notification information containing a cell ID that matches that contained in the SIB is stored in the notification information buffer 205. If notification information containing a cell ID that matches that contained in the SIB is not stored in the notification information buffer 205, the notification information processing unit 206 instructs the reception timing control unit 208 to receive all of the SIBs.

[0064] Furthermore, if notification information containing a cell ID that matches that contained in the SIB is stored, the notification information processing unit 206 determines whether notification information containing the cell ID and the "Value tag" that match those contained in the SIB is stored in the notification information buffer 205. If both the "Value tags" match, the notification information processing unit 206 ends the process because it does not need to update the notification information stored in the notification information buffer 205. In contrast, if both the "Value tags" do not match, the notification information processing unit 206 instructs the reception timing control unit 208 to receive the SIB containing the revision history of the notification information.

[0065] For example, in the example illustrated in FIG. 3 , the notification information processing unit 206 receives an input of the SIB1 from the decoding unit 204. In such a case, the notification information processing unit 206 determines whether notification information containing a cell ID that matches the cell ID contained in the SIB1 is stored in the notification information buffer 205. If notification information containing a cell ID that matches that contained in the SIB1 is not stored in the notification information buffer 205, the notification information processing unit 206 instructs the reception timing control unit 208 to receive all of the SIB1 to the SIB12.

[0066] In contrast, if notification information containing a cell ID that matches that contained in the SIB1 is stored in the notification information buffer 205, the notification information processing unit 206 determines whether notification information containing a "Value tag" that matches that contained in the SIB1 is stored in the notification information buffer 205. If notification information containing a "Value tag" that matches that contained in the SIB1 is stored in the notification information buffer 205, the notification information processing unit 206 ends the process. In contrast, if notification information containing a "Value tag" that matches that contained in the SIB1 is not stored in the notification information buffer 205, the notification information processing unit 206 instructs the reception timing control unit 208 to receive the SIB12 containing the revision history of the notification information.

[0067] On the basis of the paging information decoded by the decoding unit 204, the paging processing unit 207 instructs the reception timing control unit 208 to receive notification information. Specifically, if the paging information is input from the decoding unit 204, the paging processing unit 207 determines whether the paging indicates a call. If the paging does not indicate a call, the paging processing unit 207 determines that notification information has been changed. Then, the paging processing unit 207 instructs the reception timing control unit 208 to receive an SIB containing the revision history of the notification information.

[0068] For example, in the example illustrated in FIG. 2 , the base station 100 transmits, to the mobile terminal 200, the paging indicating that the notification information has been changed. In such a case, the paging processing unit 207 instructs the reception timing control unit 208 to receive the SIB12 containing the revision history of the notification information.

[0069] The reception timing control unit 208 controls, in accordance with an instruction from the notification information processing unit 206 or the paging processing unit 207, the timing of the reception performed by the radio receiving unit 202. Specifically, if the reception timing control unit 208 is instructed by the notification information processing unit 206 or the paging processing unit 207 to receive an SIB containing revision history of notification information, the reception timing control unit 208 controls the radio receiving unit 202 such that the radio receiving unit 202 receives the SIB. Furthermore, if the reception timing control unit 208 is instructed by the notification information processing unit 206 to receive all SIBs, the reception timing control unit 208 controls the radio receiving unit 202 such that the radio receiving unit 202 receives all of the SIB. Furthermore, if the mobile terminal 200 moves between cells, the reception timing control unit 208 controls the radio receiving unit 202 such that the radio receiving unit 202 receives an SIB containing a "Value tag".

Flow of the notification information transmission process performed by the base station according to the second embodiment

[0070] In the following, the flow of the notification information transmission process performed by the base station 100 according to the second embodiment will be described with reference to FIG. 7. FIG. 7 is a flowchart illustrating the flow of a notification information transmission process performed by the base station 100 according to the second embodiment.

[0071] As illustrated in FIG. 7 , if the notification information creating unit 104 in the base station 100 receives a request to change notification information (Yes at Step S101), the notification information creating unit 104 creates an SIB that is the target for a change (Step S102). Then, the notification information creating unit 104 outputs change information related to the notification information to the revision history creating unit 105.

[0072] On the basis of the change information related to the notification information input from the notification information creating unit 104, the revision history creating unit 105 creates an SIB containing revision history of the notification information (Step S103). Then, the notification information creating unit 104 stores, in the notification information buffer 106, both the SIB created at Step S102 and the SIB created by the revision history creating unit 105.

[0073] Subsequently, when the notification information is to be transmitted (Yes at Step S104), the transmission timing control unit 107 instructs the notification information buffer 106 to output the notification information to the encoding unit 108. When receiving the instruction, the notification information buffer 106 outputs the notification information to the encoding unit 108. Accordingly, the base station 100 transmits, to the cell formed by the base station 100, the notification information stored in the notification information buffer 106 (Step S105).

[0074] If the notification information creating unit 104 changes notification information (Yes at Step S106), the notification information creating unit 104 instructs the paging creating unit 101 to transmit the paging. Consequently, the paging creating unit 101 creates paging information and transmits the paging via the encoding unit 102, the modulating unit 103, and the radio transmitting unit 110 (Step S107).

[0075] Then, the base station 100 returns to the process performed at Step S101. If the notification information has not been changed (No at Step S106), the base station 100 returns to the process performed at Step S101 without transmitting the paging.

[0076] Furthermore, even if the base station 100 does not receive a request to change the notification information (No at Step S101), when the notification information is to be transmitted (Yes at Step S104), the base station 100 transmits the notification information (Step S107).

Flow of the notification information receiving process performed by the mobile terminal according to the second embodiment

[0077] In the following, the flow of the notification information receiving process performed by the mobile terminal 200 according to the second embodiment will be described with reference to FIG. 8. FIG. 8 is a flowchart illustrating the flow of the notification information receiving process performed by the mobile terminal 200 according to the second embodiment. FIG. 8 illustrates the flow of the notification information receiving process performed by the mobile terminal 200 that is located to a cell.

[0078] As illustrated in FIG. 8 , when the paging processing unit 207 in the mobile terminal 200 receives the paging from the base station 100 (Yes at Step S201), the paging processing unit 207 determines whether the paging indicates a call (Step S202). Then, if the paging processing unit 207 determines that the paging indicates a call (Yes at Step S202), the mobile terminal 200 controls a call (Step S203).

[0079] In contrast, if the paging does not indicate a call (No at Step S202), the paging processing unit 207 determines that notification information has been changed and instructs the reception timing control unit 208 to receive an SIB containing revision history of notification information. Accordingly, the radio receiving unit 202 receives the SIB containing the revision history of the notification information by being controlled by the reception timing control unit 208 (Step S204). The SIB is output to the notification information processing unit 206 via the demodulating unit 203 and the decoding unit 204.

[0080] Then, on the basis of the SIB containing the revision history of the notification information, the notification information processing unit 206 determines whether the notification information transmitted from the base station 100 has been updated (Step S205). If the change information contained in the SIB is not stored in the notification information buffer 205, the notification information processing unit 206 determines that the notification information has been changed (Yes at Step S205). Then, the notification information processing unit 206 updates the notification information stored in the notification information buffer 205 to the change information contained in the SIB (Step S206).

[0081] In contrast, if the change information contained in the SIB is stored in the notification information buffer 205, the notification information processing unit 206 determines that the notification information is not changed (No at Step S205) and ends the process.

[0082] Flow of the notification information receivingprocess performed when the mobile terminal according to the second embodiment moves between cells

[0083] In the following, the flow of the notification information receiving process performed when the mobile terminal 200 according to the second embodiment will be described with reference to FIG. 9. FIG. 9 is a flowchart illustrating the flow of a notification information receiving process performed when the mobile terminal 200 according to the second embodiment moves between cells. FIG. 9 illustrates the flow of the notification information receiving process performed by the mobile terminal 200 that moves between cells.

[0084] As illustrated in FIG. 9 , when the mobile terminal 200 moves between cells (Yes at Step S301), the reception timing control unit 208 in the mobile terminal 200 controls the radio receiving unit 202 such that the SIB containing a "Value tag" is received.

[0085] Consequently, when the mobile terminal 200 moves between cells (Yes at Step S301), the radio receiving unit 202 receives the SIB containing the "Value tag" (Step S302). The SIB received by the radio receiving unit 202 is output to the notification information processing unit 206 via the demodulating unit 203 and the decoding unit 204.

[0086] If the notification information processing unit 206 receives an input of the SIB from the decoding unit 204, the notification information processing unit 206 determines whether notification information containing a cell ID that matches that contained in the SIB is stored in the notification information buffer 205 (Step S303).

[0087] If notification information containing a cell ID that matches that contained in the SIB is not stored in the notification information buffer 205 (No at Step S303), the notification information processing unit 206 instructs the reception timing control unit 208 to receive all of the SIBs. Accordingly, the radio receiving unit 202 receives all of the SIBs (Step S304). Then, on the basis of all of the SIBs received by the radio receiving unit 202, the notification information processing unit 206 updates the notification information stored in the notification information buffer 205 (Step S305).

[0088] In contrast, if notification information containing a cell ID that matches that contained in the SIB is stored in the notification information buffer 205 (Yes at Step S303), the notification information processing unit 206 determines whether the "Value tags" match (Step S306). Specifically, the notification information processing unit 206 determines whether the "Value tag" of the notification information that contains a cell ID that matches that contained in the SIB stored in the notification information buffer 205 matches the "Value tag" contained in the SIB.

[0089] If the both "Value tags" match (Yes at Step S306), the notification information processing unit 206 determines that the notification information stored in the notification information buffer 205 does not need to be updated and ends the process.

[0090] In contrast, if the both "Value tags" do not match (No at Step S306), the notification information processing unit 206 instructs the reception timing control unit 208 to receive the SIB containing the revision history of the notification information. Consequently, the radio receiving unit 202 receives the SIB containing the revision history of the notification information (Step S307). Then, on the basis of the revision history contained in the SIB received by the radio receiving unit 202, the notification information processing unit 206 updates the notification information stored in the notification information buffer 205 (Step S308).

Advantage of the second embodiment

[0091] As described above, in the wireless communication system 2 according to the second embodiment, the base station 100 transmits the notification information containing the revision history. If the notification information has been changed, the base station 100 notifies, by transmitting the paging, the mobile terminal 200 that the notification information has been changed. When the mobile terminal 200 receives the notification indicating that the notification information has been changed, the mobile terminal 200 receives the revision history of the notification information instead of receiving all the pieces of notification information and then updates the notification information retained in the mobile terminal 200 on the basis of the received revision history.

[0092] Furthermore, when the mobile terminal 200 according to the second embodiment moves between cells, the mobile terminal 200 receives the SIB containing the "Value tag" and determines, on the basis of both the cell ID and the "Value tag", whether the notification information transmitted from the base station 100 has been updated. If the notification information transmitted from the base station 100 has been updated, the mobile terminal 200 receives the revision history of the notification information instead of receiving all the pieces of the notification information and then updates the notification information retained in the mobile terminal 200 on the basis of the received revision history.

[0093] Accordingly, even if notification information has been changed or even if the mobile terminal 200 according to the second embodiment moves between cells, the mobile terminal 200 receives only revision history, thus reducing the electrical power consumed when the receiving process is performed on the notification information. Furthermore, the mobile terminal 200 updates the notification information by using the change information contained in the revision history of the notification information, thus reducing the electrical power consumed when the update process is performed on the notification information.

[Third Embodiment]

[0094] The wireless communication system or the like disclosed in the present application can be implemented as various kinds of embodiments other than the embodiments described above. Accordingly, in a third embodiment, another embodiment of the wireless communication system disclosed in the present application will be described.

Revision history of notification information (1)

[0095] In the second embodiment, as in the example illustrated in FIG. 5 , a description has been given of an example in which the change information related to the notification information is created as the revision history. However, the base station 100 may also create revision history in which a "Value tag" of the notification information is associated with change information indicating that the notification information represented by the "Value tag" has been changed.

[0096] FIG. 10 is a schematic diagram illustrating an example of a revision history in which a "Value tag" is associated with change information. In the example illustrated in FIG. 10 , the revision history creating unit 105 in the base station 100 creates the revision history of the notification information in the order of the revision history R21, the revision history R22, and the revision history R23. Specifically, it is assumed that, first, the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "received electrical power corresponding to the condition for moving into a cell ID of "XXX" is changed to "3 dB"". Furthermore, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, information indicating that the "Value tag" is "1". In such a case, as in the example illustrated in FIG. 10 , the revision history creating unit 105 creates the revision history R21.

[0097] Thereafter, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "the cell ID of "YYY" is deleted from a peripheral cell list" and the change information indicating that "the cell ID of "ZZZ" is deleted from the peripheral cell list. Furthermore, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, information indicating that the "Value tag" is "2". In such a case, as in the example illustrated in FIG. 10 , the revision history creating unit 105 creates the revision history R22. The notification information indicating that the "Value tag" is "1" is different from the notification information indicating that the "Value tag" is "2" in that the change information indicating that "the cell ID of "YYY" is deleted from a peripheral cell list" and "the cell ID of "ZZZ" is deleted from a peripheral cell list" are contained or not.

[0098] Thereafter, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, the change information indicating that "the paging period is changed to "8". Furthermore, it is assumed that the revision history creating unit 105 receives, from the notification information creating unit 104, information indicating that the "Value tag" is "3". In such a case, as in the example illustrated in FIG. 10 , the revision history creating unit 105 creates the revision history R23. In other words, the notification information indicating that the "Value tag" is "2" is different from that indicating that the "Value tag" is "3" in that the change information indicating that "the paging period is changed to "8"" is contained or not.

[0099] If the notification information processing unit 206 according to the mobile terminal 200 receives the revision history of the notification information illustrated in FIG. 10 , the notification information processing unit 206 acquires, from the revision history, the change information associated with the "Value tag" that is different from the "Value tag" stored in the notification information buffer 205. Then, on the basis of the acquired change information, the notification information processing unit 206 updates the notification information stored in the notification information buffer 205.

[0100] As described above, because the base station 100 transmits the revision history in which a "Value tag" is associated with the change information, the mobile terminal 200 can update only the change information that has not been reflected in the notification information buffer 205. Accordingly, the mobile terminal 200 can reduce electrical power consumed when the update process is performed on the notification information.

Revision history of notification information (2)

[0101] In the second embodiment, as in the example illustrated in FIG. 5 , a description has been given of a case in which the change information related to the notification information is created as the revision history. However, the base station 100 may also create revision history in which the change date and time of notification information is associated with change information that has been changed at the change date and time.

[0102] FIG. 11 is a schematic diagram illustrating an example of a revision history in which the change date and time at which notification information is changed is associated with the change information. In the example illustrated in FIG. 11 , the revision history creating unit 105 in the base station 100 creates the revision history of the notification information in the order of the revision history R31, the revision history R32, and the revision history R33. Specifically, it is assumed that, first, the revision history creating unit 105 receives, at "13:25:10" from the notification information creating unit 104, the change information indicating that "received electrical power corresponding to the condition for moving to a cell ID of "XXX" is changed to "3 dB"". In such a case, as in the example illustrated in FIG. 11 , the revision history creating unit 105 creates the revision history R31.

[0103] Thereafter, if the revision history creating unit 105 receives, at "13:40:25" from the notification information creating unit 104, the change information indicating that "the cell ID of "YYY" is deleted from the peripheral cell list" and the change information indicating that "the cell ID of "ZZZ" is deleted from the peripheral cell list". In such a case, as in the example illustrated in FIG. 11 , the revision history creating unit 105 creates the revision history R32. Thereafter, it is assumed that the revision history creating unit 105 receives, at "13:52:05" from the notification information creating unit 104, the change information indicating that "the paging period is changed to "8". In such a case, as in the example illustrated in FIG. 11 , the revision history creating unit 105 creates the revision history R33.

[0104] If the notification information processing unit 206 in the mobile terminal 200 receives the revision history of the notification information illustrated in FIG. 11 , the notification information processing unit 206 acquires, from the revision history, the change information that has been updated after the notification information stored in the notification information buffer 205 was updated. Then, the notification information processing unit 206 updates the notification information stored in the notification information buffer 205 on the basis of the acquired change information.

[0105] As described above, because the base station 100 transmits the revision history in which the change date and time is associated with the change information, the mobile terminal 200 can update only the change information that has not been reflected in the notification information buffer 205. Accordingly, the mobile terminal 200 can reduce electrical power consumed when the update process is performed on the notification information.

[0106] Furthermore, the base station 100 may also create revision history containing SIB number that identifies an SIB contained in the change information illustrated in FIGS. 10 and 11 . For example, in the example illustrated in FIG. 10 , it is assumed that the change information indicating that "received electrical power corresponding to the condition for moving to a cell ID of "XXX" is changed to "3 dB" is contained in the SIB3. In such a case, the base station 100 may also create revision history that contains, together with a "Value tag", the SIB number of "3" that is used to identify the SIB containing the change information. Furthermore, in this example, it is assumed that the SIB number of the SIB3 is "3".

[0107] Accordingly, when the mobile terminal 200 stores the notification information and the SIB in an associated manner in the notification information buffer 205, the mobile terminal 200 can update the change information on the basis of the SIB number contained in the revision history of the notification information.

Revision history of notification information (3)

[0108] In the second embodiment, as in the example illustrated in FIGS. 2 and 3 , a description has been given of a case in which the SIB containing the revision history of the notification information is transmitted at the end of the notification information. However, the base station 100 may also transmit an SIB containing the notification information after an SIB containing a "Value tag". This case will be described with reference to FIG. 12 .

[0109] FIG. 12 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information. In the example illustrated in FIG. 12 , it is assumed that various kinds of information related to notification information is contained in the SIB1 to the SIB11 and assumed that the revision history of the notification information is contained in the SIB12. Furthermore, it is assumed that a "Value tag" is contained in the SIB1. In the example illustrated in FIG. 12 , the base station 100 transmits the SIB1, the SIB12, and the SIB2 to the SIB11 in the order the SIBs are listed in this sentence.

[0110] In this example, it is assumed that the notification information contained in the SIB2 has been changed. Furthermore, it is assumed that, after the mobile terminal 200 moves from the cell formed by the base station 100 to another cell, the mobile terminal 200 again moves into the cell formed by the base station 100. In such a case, the mobile terminal 200 transmits the SIB1 containing the "Value tag" from among the notification information transmitted from the base station 100. If the "Value tag" of the notification information stored in the notification information buffer 205 is different from that contained in the SIB1, the mobile terminal 200 receives the SIB12 that contains the revision history of the notification information. Then, the mobile terminal 200 updates the notification information stored in the notification information buffer 205 on the basis of the revision history of the notification information contained in the SIB12.

[0111] As described above, because the base station 100 transmits the SIB12 after the SIB1, the mobile terminal 200 can continuously receive the SIB1 and the SIB12 when the mobile terminal 200 moves cells.

Revision history of notification information (4)

[0112] In the second embodiment described above, a description has been given of a case a new SIB containing revision history of notification information is created. However, the base station 100 may also create an SIB that contains both a "Value tag" and revision history of notification information. This example will be described with reference to FIG. 13 .

[0113] FIG. 13 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information. In the example illustrated in FIG. 13 , it is assumed that both a "Value tag" and revision history of notification information are contained in the SIB1. Furthermore, various kinds of information related to notification information is contained in the SIB2 to the SIB11.

[0114] In the example illustrated in FIG. 13 , when the mobile terminal 200 moves cells, the mobile terminal 200 receives the SIB1 from among the notification information transmitted from the base station 100. Then, the mobile terminal 200 determines whether the "Value tag" of the notification information stored in the notification information buffer 205 is different from that contained in the SIB1. If both the "Value tags" differ, the mobile terminal 200 updates the notification information stored in the notification information buffer 205 on the basis of the revision history of the notification information contained in the SIB1.

[0115] As described above, because the base station 100 transmits the SIB containing both the "Value tag" and the revision history of the notification information, the mobile terminal 200 can update the notification information by only receiving the SIB when moving cells. Accordingly, in the example illustrated in FIG. 13 , the mobile terminal 200 can reduce electrical power consumed when the update process is performed on the notification information.

Revision history of notification information (5)

[0116] In the second embodiment described above, a description has been given of a case in which the revision history containing the change information related to the notification information is created. However, the base station 100 may also create, as revision history, an SIB number for identifying the SIB that contains the changed notification information. This example will be described with reference to FIG. 14 .

[0117] FIG. 14 is a schematic diagram illustrating an example of a transmission/receiving process performed on notification information. In the example illustrated in FIG. 14 , it is assumed that the SIB1 to the SIB11 contain various kinds of information related to the notification information and assumed that the SIB12 contains an SIB number for identifying an SIB in which notification information has been changed. Furthermore, it is assumed that the notification information contained in the SIB2 has been changed. Specifically, it is assumed that the SIB number of "2" for identifying the SIB2 is contained in the SIB12.

[0118] In such a case, when the mobile terminal 200 receives paging from the base station 100, the mobile terminal 200 first receives the SIB12. Then, the mobile terminal 200 acquires the SIB number contained in the SIB12 and receives the SIB indicated by the SIB number. In the example illustrated in FIG. 14 , because the SIB number of "2" is contained in the SIB12, the base station 100 receives the SIB12 after it receives the SIB2. Then, on the basis of the notification information contained in the SIB2, the base station 100 updates the notification information stored in the notification information buffer 205.

Program

[0119] The various processes performed in the embodiments described above can be implemented by programs prepared in advance and executed by a computer system such as a personal computer or a workstation. Accordingly, in the following, a computer that executes a transmission control program having the same function performed by the transmitter 10 illustrated in FIG. 1 will be described as an example with reference to FIG. 15 . Furthermore, in the following, a computer that executes a reception control program having the same function performed by the receiving apparatus 20 illustrated in FIG. 1 will be described as an example with reference to FIG. 16 .

[0120] FIG. 15 is a block diagram illustrating a computer that executes a transmission control program. As illustrated in FIG. 15 , a computer 1000 includes a random access memory (RAM) 1010, a cache 1020, an HDD 1030, a read only memory (ROM) 1040, a central processing unit (CPU) 1050, and a bus 1060. The RAM 1010, the cache 1020, the HDD 1030, the ROM 1040, and the CPU 1050 are connected by the bus 1060.

[0121] The ROM 1040 stores therein, in advance, the transmission control program having the same function as that performed by the transmitter 10 illustrated in FIG. 1 . Specifically, the ROM 1040 stores therein a revision history creating program 1041 and a transmitting program 1042. Then, the CPU 1050 reads, from the ROM 1040, the revision history creating program 1041 and the transmitting program 1042 and executes them.

[0122] By doing so, as illustrated in FIG. 15 , the revision history creating program 1041 functions as a revision history creating process 1051. Furthermore, the transmitting program 1042 functions as a transmitting process 1052. The revision history creating process 1051 corresponds to the revision history creating unit 11 illustrated in FIG. 1 . The transmitting process 1052 corresponds to the transmitting unit 12 illustrated in FIG. 1 .

[0123] FIG. 16 illustrates a block diagram illustrating a computer that executes the reception control program. As illustrated in FIG. 16 , a computer 2000 includes a RAM 2010, a cache 2020, an HDD 2030, a ROM 2040, a CPU 2050, and a bus 2060. The RAM 2010, the cache 2020, the HDD 2030, the ROM 2040, and the CPU 2050 are connected by the bus 2060.

[0124] The ROM 2040 stores therein, in advance, the reception control program having the same function as that performed by the receiving apparatus 20 illustrated in FIG. 1 . Specifically, the ROM 2040 stores therein a receiving program 2041 and an update program 2042. Then, the CPU 2050 reads, from the ROM 2040, the receiving program 2041 and the update program 2042 and executes them.

[0125] By doing so, as illustrated in FIG. 16 , the receiving program 2041 functions as a receiving process 2051. Furthermore, the update program 2042 functions as an update process 2052. The receiving process 2051 corresponds to the receiving unit 22 illustrated in FIG. 1 . The update process 2052 corresponds to the updating unit 23 illustrated in FIG. 1 .

[0126] The above-described programs 1041, 1042, 2041, and2042 are not always stored in the ROM 1040. For example, each of the programs may also be stored in a "portable physical medium", such as a flexible disk (FD), a CD-ROM, a DVD disk, a magneto-optic disk, an IC CARD, or the like, that can be inserted into the computer 1000 or 2000. Alternatively, each of the programs may also be stored in a "fixed physic almedium", such as a hard disk drive (HDD), that can be arranged inside/outside the computer 1000 or 2000. Alternatively, each of the programs may also be stored in "another computer (or a server)" connected to the computer 1000 or 2000 via a public circuit, the Internet, a LAN, a WAN, or the like. Then, the computer 1000 or 2000 may also read and execute each of the programs from the flexible disk or the like described above.

System configuration, etc

[0127] The components of each unit illustrated in the drawings are only for conceptually illustrating the functions thereof and are not always physically configured as illustrated in the drawings. In other words, the specific shape of a separate or integrated device is not limited to the drawings. Specifically, all or part of the device can be configured by functionally or physically separating or integrating any of the units depending on various loads or use conditions. For example, the notification information creating unit 104 and the revision history creating unit 105 illustrated in FIG. 4 may also be integrated.

Explanation of Reference

[0128]
1, 2 : WIRELESS COMMUNICATION SYSTEM
10 : TRANSMITTER
11 : REVISION HISTORY CREATING UNIT
12 : TRANSMITTING UNIT
20 : RECEIVING APPARATUS
21 : STORING UNIT
22 : RECEIVING UNIT
23 : UPDATING UNIT
91 : BASE STATION
92 : MOBILE TERMINAL
100 : BASE STATION
101 : PAGING CREATING UNIT
102 : ENCODING UNIT
103 : MODULATING UNIT
104 : NOTIFICATION INFORMATION CREATING UNIT
105 : REVISION HISTORY CREATING UNIT
106 : NOTIFICATION INFORMATION BUFFER
107 : TRANSMISSION TIMING CONTROL UNIT
108 : ENCODING UNIT
109 : MODULATING UNIT
110 : RADIO TRANSMITTING UNIT
111 : ANTENNA
200 : MOBILE TERMINAL
201 : ANTENNA
202 : RADIO RECEIVING UNIT
203 : DEMODULATING UNIT
204 : DECODING UNIT
205 : NOTIFICATION INFORMATION BUFFER
206 : NOTIFICATION INFORMATION PROCESSING UNIT
207 : PAGING PROCESSING UNIT
208 : RECEPTION TIMING CONTROL UNIT

1000, 2000 : COMPUTER
1010, 2010 : RAM
1020, 2020 : CACHE
1030, 2030 : HDD
1040, 2040 : ROM
1041 : REVISION HISTORY CREATING PROGRAM
1042 : TRANSMITTING PROGRAM
1050, 2050 : CPU
1051 : REVISION HISTORY CREATING PROCESS
1052 : TRANSMITTING PROCESS
1060, 2060 : BUS
2041 : RECEIVING PROGRAM
2042 : UPDATE PROGRAM
2051 : RECEIVING PROCESS
2052 : UPDATE PROCESS

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(54) **Title**: NETWORK NODE, WIRELESS DEVICE, METHODS THEREIN, FOR SENDING AND DETECTING, RESPECTIVELY, SYNCHRONIZATION SIGNAL AND AN ASSOCIATED INFORMATION

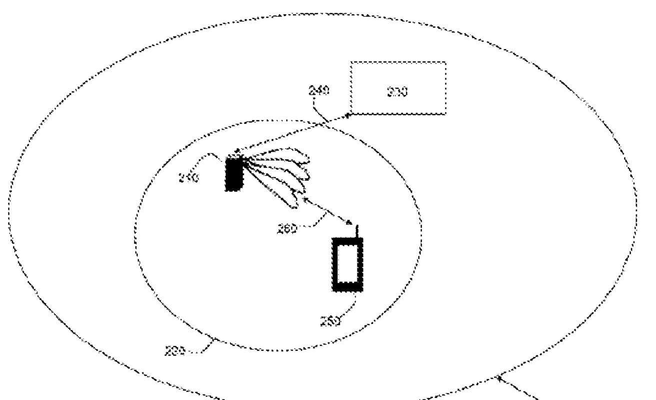

Figure 2

(57) **Abstract**: Method performed by a network node (210) for sending to a wireless device (250) a first synchronization signal and an associated information message, for synchronization of the wireless device (250) with the network node (210). The network node (210) and the wireless device (250) operate in a wireless communications network (200). The network node (210) sends the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2. For each sending of the first synchronization signal, the network node (210) sends an associated information message at a pre-defined time and frequency position in an OFDM symbol. The pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal. The associated information message is associated with the first synchronization signal.

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NETWORK NODE, WIRELESS DEVICE, METHODS THEREIN, FOR SENDING AND DETECTING, RESPECTIVELY, SYNCHRONIZATION SIGNAL AND AN ASSOCIATED INFORMATION

TECHNICAL FIELD

The present disclosure relates generally to a network node and methods therein for sending, to a wireless device, a first synchronization signal and an associated information message, for synchronization of the wireless device with the network node. The present disclosure also relates generally to the wireless device and methods therein for detecting the first synchronization signal and the associated information message. The present disclosure further relates generally to computer programs and computer-readable storage mediums, having stored thereon the computer programs to carry out these methods.

BACKGROUND

Communication devices such as terminals are also known as e.g. User Equipments (UE), wireless devices, mobile terminals, wireless terminals and/or mobile stations. Terminals are enabled to communicate wirelessly in a cellular communications network or wireless communication system, sometimes also referred to as a cellular radio system or cellular networks. The communication may be performed e.g. between two terminals, between a terminal and a regular telephone and/or between a terminal and a server via a Radio Access Network (RAN) and possibly one or more core networks, comprised within the cellular communications network.

Terminals may further be referred to as mobile telephones, cellular telephones, laptops, or surf plates with wireless capability, just to mention some further examples. The terminals in the present context may be, for example, portable, pocket-storable, hand-held, computer-comprised, or vehicle-mounted mobile devices, enabled to communicate voice and/or data, via the RAN, with another entity, such as another terminal or a server.

The cellular communications network covers a geographical area which is divided into cell areas, wherein each cell area being served by an access node such as a base station, e.g. a Radio Base Station (RBS), which sometimes may be referred to as e.g. "eNB", "eNodeB", "NodeB", "B node", or BTS (Base Transceiver Station), depending on the technology and terminology used. The base stations may be of different classes such as e.g. macro eNodeB, home eNodeB or pico base station, based on transmission power and thereby also cell size. A cell is the geographical area where radio coverage is provided by the base station at a base station site. One base station, situated on the base station site, may serve one or several cells. Further, each base station may support one or several communication technologies. The base stations communicate over the air interface operating on radio frequencies with the terminals within range of the base stations. In the context of this disclosure, the expression Downlink (DL) is used for the transmission path from the base station to the mobile station. The expression Uplink (UL) is used for the transmission path in the opposite direction i.e. from the mobile station to the base station.

In 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE), base stations, which may be referred to as eNodeBs or even eNBs, may be directly connected to one or more core networks.

3GPP LTE radio access standard has been written in order to support high bitrates and low latency both for uplink and downlink traffic. All data transmission is in LTE controlled by the radio base station.

The development of the 5th Generation (5G) access technology and air interference is still very premature but there have been some early publications on potential technology candidates. A candidate on a 5G air interface is to scale the current LTE, which is limited to 20 Mega Hertz (MHz) bandwidth, N times in bandwidth with 1/N times shorter time duration, here abbreviated as LTE-Nx. A typical value may be N=5 so that the carrier has 100 MHz bandwidth and 0.1 millisecond slot lengths. With this scaled approach, many functions in LTE can be re-used in LTE-Nx, which would simplify standardization effort and allow for a reuse of technology components.

The carrier frequency for an anticipated 5G system could be much higher than current 3G and 4th Generation (4G) systems, values in the range 10-80 Giga Hertz (GHz) have been discussed. At these high frequencies, an array antenna may be used to achieve coverage through beamforming gain, such as that depicted in **Figure 1**. Figure 1 depicts a 5G system example with three Transmission Points (TPs), Transmission Point 1 (TP1), Transmission Point 2 (TP2), Transmission Point 3 (TP3) and a UE. Each TP utilizes beamforming for transmission. Since the wavelength is less than 3 centimeters (cm), an array antenna with a large number of antenna elements may be fit into an antenna enclosure with a size comparable to 3G and 4G base station antennas of today. To achieve a reasonable link budget, a typical example of a total antenna array size is comparable to an A4 sheet of paper.

The beams are typically highly directive and give beamforming gains of 20 decibels (dB) or more since so many antenna elements participate in forming a beam. This means that each beam is relatively narrow in horizontal and/or azimuth angle, a Half Power Beam Width (HPBW) of 5 degrees is not uncommon. Hence, a sector of a cell may need to be covered with a large number of potential beams. Beamforming can be seen as when a signal is transmitted in such a narrow HPBW that it is intended for a single wireless device or a group of wireless devices in a similar geographical position. This may be seen in contrast to other beam shaping techniques, such as cell shaping, where the coverage of a cell is dynamically adjusted to follow the geographical positions of a group of users in the cell. Although beamforming and cell shaping use similar techniques, i.e., transmitting a signal over multiple antenna elements and applying individual complex weights to these antenna elements, the notion of beamforming and beams in the embodiments described herein relates to the narrow HPBW basically intended for a single wireless device or terminal position.

In some embodiments herein, a system with multiple transmission nodes is considered, where each node has an array antenna capable of generating many beams with small HPBW. These nodes may then for instance use one or multiple LTE-Nx carriers, so that a total transmission bandwidth of multiples of hundreds of MHz can be achieved leading to downlink peak user throughputs reaching as much as 10 Gigabytes (Gbit/s) or more.

In LTE access procedures, a UE may first search for a cell using a cell search procedure, to detect an LTE cell and decode information required to register to the cell. There may also be a need to identify new cells, when a UE is already connected to a cell to find neighbouring cells. In this case, the UE may report the detected neighbouring cell identity and some measurements, to its serving cell, as to prepare for a handover. In order to support cell search, a unique Primary Synchronization Signal (PSS) and Secondary Synchronization Signal (SSS) may be transmitted from each eNB. The synchronizations signals are used for frequency synchronization and time synchronization. That is, to align a receiver of wireless device, e.g., the UE, to the signals transmitted by a network node, e.g., the eNB. The PSS comprises information that allows the wireless device in LTE to detect the 5 ms timing of the cell, and the cell identity within the cell-identity group. The SSS allows the wireless device in LTE to obtain frame timing and the cell-identity group. The PSS may be constructed from a Zadoff-Chu sequence of length 63, mapped to the center 64 subcarriers where the middle, so called DC subcarrier is unused. There may be three PSS in LTE, corresponding to three physical layer identities. The SSS may be constructed from two interleaved M-sequences of length 31 respectively, and by applying different cyclic shifts of each of the two M-sequences, different SSS may be obtained. In total, there may be 168 valid combinations of the two M-sequences, representing the cell identity groups. Combining the PSS and SSS, there may be thus in total 504 physical cell identities in LTE.

When a cell has been found, the UE may proceed with further steps to be associated with this cell, which may then be known as the serving cell for this UE. After the cell is found, the UE may read System Information (SI) in e.g., the Physical Broadcast CHannel (PBCH), known as the Master Information Block (MIB), which is found in a time frequency position relative to the PSS and SSS locations. The SI comprises all the information needed by a wireless device to access the network using a random access procedure. After the MIB is detected, the System Frame Number (SFN) and the system bandwidth are known. The UE may let the network know about its presence by transmitting a message in the Physical Random Access CHannel (PRACH).

When a cell has multiple antennas, each antenna may transmit an individual encoded message to the wireless device or UE, thereby multiplying the capacity by the number of layers transmitted. This is well known as MIMO transmission, and the number of layers transmitted is known as the rank of the transmission. Beamforming, traditionally, is equivalent to a rank 1 transmission, where only one encoded message is transmitted, but simultaneously from all antennas with individually set complex beamforming weights per antenna. Hence, in beamforming, only a single layer of Physical Downlink Shared CHannel (PDSCH) or Evolved Physical Downlink Control CHannel (EPDCCH) is transmitted in a single beam. This beamforming transmission is also possible in LTE, so after a UE has been associated with a cell, a set of N=1,2,4 or 8 Channel State Information Reference Signals (CSI-RS) may be configured for measurement reference at the UE, so that the UE may report a preferred rank 1 Nx1 precoding vector containing the complex beamforming weights based on the CSI-RS measurement. The precoding vector may be selected from a codebook of rank 1 precoding vectors. In Rel-8, there are 16 rank 1 precoding vectors defined, and in Rel-12 a new codebook was designed with 256 rank 1 precoding vectors.

A "beam" may thus be the result of a certain precoding vector applied for one layer of transmitted signal across the antenna elements, where each antenna element may have an amplitude weight and a phase shift in the general case, or equivalently, the signal transmitted from the antenna element may be multiplied with a complex number, the weight. If the antenna elements are placed in two or three dimensions, and thus, not only on a straight line, then two dimensional beamforming is possible, where the beam pointing direction may be steered in both horizontal and azimuth angle. Sometimes, also three

Dimensional (3D) beamforming is mentioned, where also a variable transmit power has been taken into account. In addition, the antenna elements in the antenna array may consist of different polarizations, and hence it is possible, by adjusting the antenna weights, to dynamically alter the polarization state of the transmitted electromagnetic wave. Hence, a two dimensional array with elements of different polarizations may give a large flexibility in beamforming, depending on the antenna weights. Sometimes, a certain set of precoding weights are denoted as a "beam state", generating a certain beam in azimuth, elevation and polarization as well as power.

The most flexible implementation may be to use a fully digital beamformer, where each weight may be applied independent of each other. However, to reduce hardware cost, size and power consumption, some of the weighting functionality may be placed in hardware, e.g., using a Butler matrix, whereas other parts may be controlled in software. For instance, the elevation angle may be controlled by a Butler matrix implementation, while the azimuth angle may be controlled in software. A problem with the hardware beamforming may be that it involves switches and phase shifters, which may have some switching latency, making instant switching of beam unrealizable.

The PBCH is transmitted using the Common Reference Signals (CRS) as a demodulation reference. Since the PSS, SSS and the PBCH channel are intended for any UE that wishes to attach to the cell, they are typically transmitted in a cell broad coverage, typically using e.g., 120 degree sectors. Hence, such signals are not beamformed in LTE, as it is a risk that, e.g., the PSS and SSS will be in the side lobe or even in a null direction of the beamforming radiation pattern. This would lead to failure in synchronizing to the cell, or failure in detecting MIB.

Existing methods for transmission of synchronization signals from a network node to a wireless device are designed for wide area coverage at lower carrier frequencies of transmission than those expected to be used in future systems. These current methods may lead to numerous synchronization failures when used in communication systems using high frequency carriers, such as those projected to be used in the future 5G system.

SUMMARY

It is an object of embodiments herein to improve the performance in a wireless communications network by providing an improved way for a network node to send synchronization signals, for synchronization of the wireless device with the network node and for a wireless device to detect these synchronization signals. In some embodiments, the network may use beamforming for transmitting the synchronization signals to the wireless device.

According to a first aspect of embodiments herein, the object is achieved by a method performed by a network node for sending, to a wireless device, a first synchronization signal and an associated information message. This is done for synchronization of the wireless device with the network node. The network node and the wireless device operate in a wireless communications network. The network node sends the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2. The network node sends, for each sending of the first synchronization signal, the associated information message at a pre-defined time and frequency position in an OFDM symbol. The pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal. The associated information message is associated with the first synchronization signal.

According to a second aspect of embodiments herein, the object is achieved by a method performed by the wireless device for detecting the first synchronization signal and the associated information message sent by the network node. This is done for synchronization of the wireless device with the network node. The network node and the wireless device operate in the wireless communications network. The wireless device detects the first synchronization signal. The first synchronization signal has been sent by the network node in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2. The wireless device detects the associated information message at the pre-defined time and frequency position. The pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal. The associated information message is associated with the first synchronization signal. The wireless device obtains subframe timing and/or frame timing by detecting an index comprised in the associated information message.

According to a third aspect of embodiments herein, the object is achieved by the network node, configured to send to the wireless device the first synchronization signal and the associated information message. This is done for synchronization of the wireless device with the network node. The network node and the wireless device are configured to operate in the wireless communications network. The network node is configured to send the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2. For each sending of the first synchronization signal, the network node is configured to send the associated information message at the pre-defined frequency position in a pre-defined OFDM symbol, i.e., the time position. The pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal. The associated information message is associated with the first synchronization signal.

According to a fourth aspect of embodiments herein, the object is achieved by the wireless device, configured to detect the first synchronization signal and the associated information message configured to be sent by the network node. This is done for synchronization of the wireless device with the network node. The network node and the wireless device are configured to operate in the wireless communications network. The wireless device is configured to detect the first synchronization signal. The first synchronization signal is configured to have been sent by the network node in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2. The wireless device is further configured to detect the associated information message at a pre-defined time and frequency position. The pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal. The associated information message is associated with the first synchronization signal. The wireless device is further configured to obtain subframe timing and/or frame timing by detecting the index comprised in the associated information message.

According to a fifth aspect of embodiments herein, the object is achieved by a computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method performed by the network node.

According to a sixth aspect of embodiments herein, the object is achieved by a computer-readable storage medium, having stored thereon the computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method performed by the network node.

According to a seventh aspect of embodiments herein, the object is achieved by a computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method performed by the wireless device.

According to an eighth aspect of embodiments herein, the object is achieved by a computer-readable storage medium, having stored thereon the computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method performed by the wireless device.

By the network node repeatedly transmitting the same first synchronization signal in N OFDM symbols within a subframe, the wireless device may more likely detect the first synchronization signal and the associated information message, in at least one of the used symbols. Therefore a way for the wireless device to synchronize with the network node is provided that is optimized for high frequency carriers, using narrow beams. This may be implemented utilizing beamforming, for example, by the network node transmitting the same first synchronization signal in a scanned manner, such as in a new beam in each OFDM symbol, so that the wireless device may more likely detect the first synchronization signal and the associated information message, in at least one of the beams. In the embodiments utilizing beamforming, the network node does not need to know which beam is preferable for the wireless device, for the wireless device to be able to successfully detect the first synchronization signal and the associated information message, as the first synchronization signal and the associated information are transmitted in multiple beams.

Further advantages of some embodiments disclosed herein are discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples of embodiments herein are described in more detail with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram illustrating a 5G system example with three TPs.

Figure 2 is a schematic block diagram illustrating embodiments in a wireless communications network, according to some embodiments.

Figure 3 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 4 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 5 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 6 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 7 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 8 is a schematic diagram illustrating embodiments of a method in a network node, according to some embodiments.

Figure 9 is a schematic diagram illustrating embodiments of a method in a wireless device, according to some embodiments.

Figure 10 is a flowchart illustrating embodiments of a method in a wireless device, according to some embodiments.

Figure 11 is a schematic diagram illustrating embodiments of a method in a wireless communications network, according to some embodiments.

Figure 12 is a schematic diagram illustrating embodiments of a method in a wireless communications network, according to some embodiments.

Figure 13 is a block diagram of a network node that is configured according to some embodiments.

Figure 14 is a block diagram of a wireless device that is configured according to some embodiments.

DETAILED DESCRIPTION

As part of the solution according to embodiments herein, one or more problems that may be associated with use of at least some of the prior art solutions, and that may addressed by embodiments herein will first be identified and discussed.

In general terms, embodiments herein relate to the fact that at high, e.g., >10 GHz, carrier frequencies, the number of antenna elements at the transmitter and/or receiver side may be significantly increased compared to common 3G and 4G systems, which typically operate at frequencies below 3 GHz. In such systems, the increased path loss may be compensated for by beamforming. If these beams are narrow, many beams may be needed to span a coverage area.

Also in general terms, embodiments herein relate to the fact that since synchronization and system information has to be transmitted in a narrow beam, in horizontal and azimuth angles, to maintain cell coverage and link reliability, it is then a problem how to transmit these signals and how the user terminal, e.g., the wireless device, find cells, i.e. to perform cell search, and how to synchronize time and frequency of the network. It is further a problem how to attain system information from the network when this information is transmitted using beamforming and how to acquire symbol and subframe synchronization.

One of the problems addressed by embodiments herein is how to transmit synchronization signals from a network node to a wireless device in a wireless communications network using a high frequency carrier that is subject to higher path loss relative a low frequency carrier, so that detection by the wireless device is optimized and synchronization failures for failure of detection of synchronization signals are decreased.

For example, when using beamforming, one of the particular problems addressed by embodiments herein is how to use the narrow beams that may be needed to provide the high beamforming gain that may be required to achieve cell coverage in systems using high frequency carriers, also for synchronization and transmission of basic system information.

In many cases, such as a wireless device initial access, or when the wireless device is searching for additional cells, it is not possible for the network, e.g., a network node controlling one or more Transmission Points (TPs), each of the TPs transmitting Transmission Point (TP) beams, to direct a beam towards a wireless device with the necessary signals for these operations, since the useful beam, or precoding vector, for the particular wireless device is not known to the network, e.g., the network node.

Hence, there may be a problem in a network, e.g., the network node, for how to transmit synchronization signals as well as basic system information, e.g. MIB, to the wireless device in a beam-formed system.

As a consequence of this, it is a problem for a wireless device how to time and frequency synchronize to a cell and how to acquire system information and how to perform handover operations.

It is further a detailed problem how the wireless device may attain the frame and subframe synchronization respectively as well as the Orthogonal Frequency Division Multiplexing (OFDM) symbol synchronization.

These problems are further discussed below.

A set of TPs may be considered wherein each TP can, by use of an array antenna, generate transmission of a larger number of different beams, wherein the beams may have different main lobe pointing direction and/or transmit polarization state.

A given beam may be represented by a certain precoding vector, where for each antenna element a signal is replicated and transmitted over, an amplitude and/or phase weight is applied. The choice of these weights thus may determine the beam, and, hence, the beam pointing direction, or "beam state".

The possibility to choose from a large number of beams to be transmitted from a TP may be typical for a 5G system deployed at higher carrier frequencies above 10 GHz, where the antenna may consist of many antenna elements to achieve a large array gain. However, larger number of beams may be applied also in systems operating at lower frequencies, e.g., below 10 GHz, for improved coverage, with the drawback of a larger total antenna size, since the wavelengths are longer.

At higher carrier frequencies, an antenna array consisting of multiple antenna elements may be used to compensate for the reduced aperture size of each element, which is a function of the carrier frequency, compared to systems operating at traditional cellular carrier frequencies, i.e., up to 5 GHz. Moreover, the large antenna gain may in turn containing the complex beamforming weights be needed to overcome the path loss at higher frequencies. The large array gain and many antenna elements may result in that each generated beam is rather narrow, when expressed in terms of HPBW, typically only 5-10 degrees or even smaller, depending on the particular design of the array antenna. Usually, two-dimensional beamforming may be desirable, where a beam may be steered in both an azimuthal and a horizontal direction simultaneously. Adding also the transmit power to a variable beam, the coverage of the 2D-beam may be controlled, so that a 3D beamforming system may be achieved.

Since the large array gain may be needed also for synchronization and broadcast control channels, e.g., carrying basic system information for accessing the cell, these signals may need to be beam-formed as well.

Synchronization is a cornerstone in accessing a wireless communications network. The synchronization may be performed on several levels, the initial time and frequency synchronization may be needed to tune the receiver to the used OFDM time frequency grid of resource elements, as the OFDM symbol boundary. Then, synchronization may also be needed to detect the subframe boundaries, e.g., in LTE, a subframe consists of 14 OFDM symbols in the case of normal Cyclic Prefix (CP) length. Furthermore, the frame structure may need to be detected, so the wireless device knows when a new frame begins, e.g., in LTE, a frame consists of 10 subframes.

Embodiments herein describe a method performed by a network, e.g., a network node, to enable the use of multiple transmit beams and at the same time provide any of: rapid cell detection, system information acquisition and symbol, subframe and frame synchronization, for a wireless device that may try to connect to a cell, e.g., served by the network node. The proposed method also may seamlessly allow for different network implementations, e.g., a network node implementations, and wireless device implementations, which may be important, since some implementations may use analog beamforming networks where the beam switching time using analog components may be too long for a switch to be performed within the time between two OFDM symbols, i.e., at a fraction of the CP length. Also, some wireless device implementations may have a restriction in, e.g., cell search computation power so that less frequent cell searches than once per OFDM symbol should not unnecessarily restrict the possibility to access the cell, other than potentially an increased access delay.

Embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which examples of the claimed subject matter are shown. The claimed subject matter may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the claimed subject matter to those skilled in the art. It should also be noted that these embodiments are not mutually exclusive. Components from one embodiment may be tacitly assumed to be present/used in another embodiment.

Figure 2 depicts a **wireless communications network 200** in which embodiments herein may be implemented. The wireless communications network 200 may for example be a network such as a Long-Term Evolution (LTE), e.g. LTE Frequency Division Duplex (FDD), LTE Time Division Duplex (TDD), LTE Half-Duplex Frequency Division Duplex (HD-FDD), LTE operating in an unlicensed band, Wideband Code Division Multiple Access (WCDMA), Universal Terrestrial Radio Access (UTRA) TDD, Global System for Mobile communications (GSM) network, GSM/Enhanced Data Rate for GSM Evolution (EDGE) Radio Access Network (GERAN) network, EDGE network, network comprising of any combination of Radio Access Technologies (RATs) such as e.g. Multi-Standard Radio (MSR) base stations, multi-RAT base stations etc., any 3rd Generation Partnership Project (3GPP) cellular network, WiFi network, Worldwide Interoperability for Microwave Access (WiMax), 5G system or any cellular network or system.

The wireless communications network 200 comprises a **transmission point**, or TP, **210**. The transmission point 210 transmits one or more TP beams. The transmission point 210 may be, for example, a base station such as e.g., an eNB, eNodeB, or a Home Node B, a Home eNode B, femto Base Station, BS, pico BS or any other network unit capable to serve a device or a machine type communication device in the wireless communications network 200. In some particular embodiments, the transmission point

210 may be a stationary relay node or a mobile relay node. The wireless communications network 200 covers a geographical area which is divided into cell areas, wherein each cell area is served by a TP although, one TP may serve one or several cells, and one cell may be served by more than one TP. In the non-limiting example depicted in Figure 2, the transmission point 210 serves **a cell 220**. The transmission point 210 may be of different classes, such as e.g. macro eNodeB, home eNodeB or pico base station, based on transmission power and thereby also cell size. Typically, the wireless communications network 200 may comprise more cells similar to cell 220, served by their respective one or more TPs. This is not depicted in Figure 2 for the sake of simplicity. The transmission point 210 may be referred to herein as a **network node 210**. The network node 210 controls one or more TPs, such as any of the network node 210.

The network node 210 may support one or several communication technologies, and its name may depend on the technology and terminology used. In 3GPP LTE, the network node 210, which may be referred to as eNodeBs or even eNBs, may be directly connected to **one or more networks 230**.

The network node 210 may communicate with the one or more networks 230 over a **link 240**.

A number of wireless devices are located in the wireless communications network 200. In the example scenario of Figure 2, only one wireless device is shown, **wireless device 250**. The wireless device 250 may communicate with the network node 210 over a **radio link 260**.

The wireless device 250 is a wireless communication device such as a UE which is also known as e.g. mobile terminal, wireless terminal and/or mobile station. The device is wireless, i.e., it is enabled to communicate wirelessly in the wireless communication network 200, sometimes also referred to as a cellular radio system or cellular network. The communication may be performed e.g., between two devices, between a device and a regular telephone and/or between a device and a server. The communication may be performed e.g., via a RAN and possibly one or more core networks, comprised within the wireless communications network 200.

The wireless device 250 may further be referred to as a mobile telephone, cellular telephone, or laptop with wireless capability, just to mention some further examples. The wireless device 250 in the present context may be, for example, portable, pocket-storable, hand-held, computer-comprised, or vehicle-mounted mobile devices, enabled to communicate voice and/or data, via the RAN, with another entity, such as a server, a laptop, a Personal Digital Assistant (PDA), or a tablet computer, sometimes referred to as a surf plate with wireless capability, Machine-to-Machine (M2M) devices, devices equipped with a wireless interface, such as a printer or a file storage device or any other radio network unit capable of communicating over a radio link in a cellular communications system. Further examples of different wireless devices, such as the wireless device 250, that may be served by such a system include, modems, or Machine Type Communication (MTC) devices such as sensors.

Embodiments of methods performed by the network node 210 and the wireless device 250 will first be described in detail, with illustrative examples, in relation to Figures 2-8. An overview of the specific actions that are or may be carried out by each of the network node 210 and the wireless device 250 to perform these examples, among others, will then be provided in relation to Figures 9 and 10.

In embodiments herein, a first synchronization signal such as a PSS may be transmitted by the network node 210 to the wireless device 250, repeatedly, N times, in N different OFDM symbols within a subframe, or across multiple subframes. The N transmissions need not occur in adjacent OFDM symbols, they may occur in every other OFDM symbol or more generally even in different subframes or frames. For each PSS transmission instance, the TP, e.g., the network node 210 or TP 210, may alter one or several of the parameters associated with the transmission, such as the azimuth angle, the horizontal angle, the transmit power or the polarization state. A given setting of all these possible transmission parameters is defined here as a beamforming state. Hence, the network node 210 or TP 210 may scan the 3D beamforming and polarization space in up to N different beamforming states, and in each state, the network node 210 or TP 210 may transmit the same PSS to provide synchronization for a UE, such as the wireless device 250, in any of these 3D positions. After these N transmissions have been performed, the 3D scan may start over from the beginning again, and the value N may, if needed for the wireless device 250, be specified in the standard, or it may also be signaled to the wireless device 250 by system information, or obtained prior to accessing the 5G carrier through signaling on a legacy system, such as LTE. The PSS may be taken by the network node 210 from a large set of sequences, similar to the PSS used in LTE, where the detection of the PSS may give the wireless device 250 information about a physical cell ID, such as a physical cell ID of cell 220. The PSS may also be used by the wireless device 250 to get a rough time and frequency synchronization. Note that the embodiments described herein are not limited to use the same or similar PSS as used in LTE, a completely different design or sequence length may also be considered.

The UE, such as the wireless device 250, in a favorable position for one, or several, of the N beam states may successfully detect the PSS, when this beam state is used, and may also acquire a physical cell ID, such as the physical cell ID of cell 220, if an LTE type of PSS is used. The network node 210 or TP 210 may also transmit an associated information message such as a SSS, at a known location relative to the PSS. So, when the PSS in a certain OFDM symbol has been detected by the wireless device 250, the wireless device 250 may also find the associated SSS at a different time and/or frequency position relative to the PSS. The SSS may then be transmitted by the network node 210 with the same beamforming state as the associated PSS. One way to implement this is for the network node 210 to transmit the SSS multiplexed with the PSS, in the same OFDM symbol, see **Figure** 3. Another alternative may be to split the SSS in two parts, where each part is on either side of the PSS, to get a symmetric transmission of PSS and SSS with respect to the center frequency.

Figure 3 depicts an example showing a subframe of 14 OFDM symbols, where the PSS and SSS are transmitted by the network node 210 in the same symbol, but at different frequency locations, i.e. subcarrier sets. In each OFDM symbol, a different beam state (B1...B14) may be used by the network node 210 to scan the beams in, for example, the horizontal angle and the azimuth angle. Furthermore, the PBCH, carrying system information, may also be transmitted, by the network node 210, in the same OFDM symbol as the associated PSS and SSS, and in this example, split on both sides of the PSS. Thus, in some embodiments, one or more PBCH may be associated with one PSS. Note that the system bandwidth may be larger than what is shown in this figure. Here, only the concept of frequency multiplexing the PSS/SSS/PBCH is illustrated. The OFDM symbol may also contain other control signaling, or the shared data channel, outside, i.e., on both sides, the frequency band, that carries the PSS/SSS/PBCH. The network/TP, e.g., the network node 210 or TP 210, may, with this arrangement, transmit each OFDM symbol using a different beamforming state. Alternatively, the network node 210 or TP 210 may transmit the PSS/SSS/PBCH part of the OFDM symbol with a first beamforming state and the remainder of the OFDM symbol, e.g., on both sides, with beamforming states that are independently selected and may thus be different from the first beamforming state. In this way, for instance, the shared data channel may be frequency multiplexed with the PSS/SSS/PBCH and yet, these, i.e., the PSS/SSS/PBCH, are using different beams, i.e. beamforming states.

In some embodiments herein, the SSS and one or more PBCH associated, i.e., transmitted, with a particular PSS, may be collectively referred to herein as a message that is associated to the PSS, i.e., an associated information message.

However, different from the PSS, each SSS may contain information about the subframe timing, such as the subframe offset and/or the frame offset relative the SSS time position. Hence, different Secondary Synchronization (SS) sequences may be transmitted by the network node 210 for each OFDM symbol, and thus, up to N different SSS may be used by the network node 210. By detecting which SS sequence is transmitted in a certain OFDM symbol, i.e. a "sequence index", the wireless device 250 may acquire at least the subframe synchronization, by using a pre-defined unique mapping between the sequence index and the relative position of the OFDM symbol and the subframe boundaries. Hence, the subframe synchronization is achieved, in the sense that the wireless device 250 may know where the subframe begins and ends. The SSS may also be used by the wireless device 250 to acquire the frame synchronization; however, this may require the use of additional SSS sequences. If only the subframe synchronization is required, or if the PSS/SSS is only transmitted in one, pre-defined subframe within the frame, then the same SSS may be repeatedly used by the network node 210 in every subframe carrying SSS; while in the case also frame synchronization may be needed from SSS by the wireless device 250, then different subframes within the frame may need to use unique SSS sequences to be able to acquire the relative distance to the frame boundaries from the detected OFDM symbol.

The SSS used in embodiments herein may or may not be equal to the LTE SSS. Since there are only 168 different SSS in LTE, these may not be enough if also used for subframe synchronization in addition to time and frequency synchronization, since a different SSS may be used by the network node 210 in each beam. However, a larger set of SSS may be defined. This may, in different embodiments, be defined as an extension of the LTE SSS, by transmitting from the network node 210, in each OFDM symbol, additional cyclic shift combinations of the two interleaved M-sequences. In another embodiment, the network node 210 may use the LTE SSS together with at least a third sequence, or a reference signal, for instance, the reference signal used when demodulating the PBCH.

Moreover, to acquire system information, the PBCH may be transmitted by the network node 210 in the same beam, and thus OFDM symbol, as the SSS, at a known location relative to the SSS and/or PSS. The PBCH may be transmitted together with a demodulation reference signal which resides in the same OFDM symbol as the PBCH, i.e., the reference signal for PBCH demodulation and the PBCH itself are precoded with the same beamforming weight vector, i.e. the same beam state. Hence, the wireless device 250 is not allowed to interpolate the channel estimates across OFDM symbols where different beam states have been used. Thus, in a sense, these reference signals are beam specific.

In one embodiment, the same PBCH information is transmitted by the network node 210 in each transmission instance within a frame. In a wireless device 250 implementation embodiment, the wireless device 250 may accumulate the PBCH from multiple transmissions from the network node 210, e.g., multiple OFDM symbols and thus multiple beams, and thus improve the reception performance of the PBCH, which contains the system information. In some cases, the wireless device 250 detects a signal in multiple beams and it may, after detecting the PSS with sufficient power, use the associated PBCH in the same beam, to accumulate energy for the PBCH detection. However, the channel estimations in the wireless device 250 implementation may need to be repeated in each OFDM symbol, since beam specific RS may be used. This may enable coherent receive combining of multiple beams which, in addition to the beamforming gain, may further enhance the MIB reception by the wireless device 250. The wireless device 250 may in a further embodiment also discard PBCH reception in the OFDM symbols, i.e. beams, where the PSS has poor detection performance, as to avoid capturing noisy estimates into the PBCH energy accumulation.

It is possible that the wireless device 250 may detect the PSS in more than one OFDM symbol, since the 3D beams may have overlapping coverage, either in terms of overlapping beam patterns or via multipath reflections in the propagation channel. In this case, the wireless device 250 implementation may estimate which of the successfully detected OFDM symbols comprised the PSS detection with the highest receive quality, and use only this when determining the subframe and/or frame timing, to ensure good synchronization performance. It is also an implementation embodiment for the network/TP side, e.g., the network node 210 or TP 210, to use fewer and/or wider than N beams for the PSS, where N is a specified upper limit on the number of supported beams in a 5G network, in which case there are more than a single beam with good PSS detection possibility for the wireless device 250. Using wider beams reduces the coverage of each beam, but in some situations coverage may be less important, such as small cells. This embodiment with wider beams may have the advantage that PSS detection is more rapid, and the normal LTE cell search algorithm of relatively low complexity may be re-used in the wireless device 250.

A further advantage of at least some embodiments described herein may be that there may be no need for the wireless device 250 to search for beams at the initial PSS detection; the wireless device 250 simply may detect successfully when a 3D beamforming state matches the wireless device 250 position in the cell 220. Hence, the use of beams is agnostic to the wireless device 250, at least at this initial stage of PSS detection. See Figure 3 for an example of how the PSS/SSS and PBCH may be transmitted by the network node 210 in the described embodiment.

In an alternative embodiment to the above described method, the same SSS sequence may be transmitted in each used OFDM symbol/beam state, while the frame and/or subframe offset may be instead explicitly indicated in the PBCH in the associated OFDM symbol. Hence, MIB detection by the wireless device 250 may in this embodiment be required before frame synchronization may be achieved. A benefit of this embodiment may be that only one SSS is used, or consumed, per TP, repeatedly in all OFDM symbols, while the drawback may be that the MIB changes in each OFDM symbol, so coherent combining over beams may not be used by the wireless device 250. In addition, a beam index n={1,...,N} may be signaled in the PBCH, to inform the wireless device 250 on which beam state of the maximally possible N beam states was used in the particular OFDM symbol. The PBCH may also comprise explicit signaling of the subframe offset and/or the frame offset. In some embodiments, the beam state n may not be informed to the wireless device 250, but this offset signaling still provides necessary information to the wireless device 250 to be able to acquire subframe and/or frame synchronization.

In yet an alternative embodiment, the SSS may be used by the wireless device 250 for detecting the subframe offset and the PBCH may be used by the wireless device 250 to detect the frame offset. Hence, the PBCH message may be the same for all OFDM symbols/beams within one subframe but may need to change from subframe to subframe, since the frame offset changes. See the figures below for illustrative examples. In this embodiment, at most 14 different SSS may be required, and the set of SSS may then be repeated in the next subframe. This is sufficient since SSS is only used to acquire the subframe timing.

Figure 4 depicts an example showing a subframe of 14 OFDM symbols, where the PSS and SSS are transmitted by the network node 210 in different symbols, with a time offset, in this case one slot, i.e., 7 OFDM symbols. Furthermore, the PBCH, carrying system information, is also transmitted by the network node 210 in the same OFDM symbol as the associated PSS and SSS, and in this example split on both sides of the

PSS. Note that the system bandwidth may be larger than what is shown in this figure. Here only the concept of frequency multiplexing the PSS/PBCH or SSS/PBCH is illustrated, and the OFDM symbol may also contain other control signaling or the shared data channel. The network/TP, e.g., the network node 210 or TP 210, may, with this arrangement, transmit each OFDM symbol using a different beamforming state. But in this example, the same beamforming state is used in symbol k and k+7 in the subframe, where k=0,...,6. So a UE, such as the wireless device 250, that detects the PSS in OFDM symbol k due to a beneficial beamforming state, may also get the same beamforming state in symbol k+7 when detecting SSS and PBCH. Hence, in each OFDM symbol in each slot, a different beam state, e.g., B1...B7, may be used by the network node 210 to scan the beams in, for example, the horizontal angle and the azimuth angle. An advantage of this separation in time between the PSS and SSS, e.g., 7 OFDM symbols, compared to the embodiment in Figure 3, is that the PSS and SSS together may be used to enhance the frequency synchronization, which is more difficult by the arrangement in Figure 3, since the same OFDM symbol is used for PSS and SSS.

Figure 5 depicts an example showing a positive detection by the wireless device 250 of PSS in OFDM symbol k=5, and thus, also SSS and PBCH detection in OFDM symbol k=12, since the network node 210 or TP 210 uses the same beamformer state in symbol k=5 and k=12 from which the wireless device 250 acquires at least the subframe offset Delta_S = 12 to the start of the subframe from either the SSS, for the embodiment where each SSS is different, or the PBCH information. In Figure 5, subframe offset, as used herein, is represented as "symbol offset".

Figure 6 depicts an example showing a positive detection by the wireless device 250 of a beam in OFDM symbol k=5, PSS, and k=12, SSS, in subframe n. The wireless device 250 acquires the subframe offset and the frame offset from the detection of SSS and/or the detection of PBCH. In Figure 6, subframe offset, as used herein, is represented as "symbol offset", and frame offset, as used herein, is represented as "subframe offset". An alternative embodiment may use SSS for detecting by the wireless device 250, the subframe offset and PBCH to detect the frame offset. Hence, the PBCH message is the same for all OFDM symbols/beams within one subframe, but may need to change from subframe to subframe, since the frame offset changes.

In Figure 6, multiple subframes are used to allow for the network node 210 or TP 210 to use more than 7 beam states, i.e. N>7, in the scanning procedure. In this example, N=7n beams may be scanned if n is the number of used subframes. If this many beams are unnecessary and it is determined that N<8 is sufficient, only a single subframe may be used by the wireless device 250 for this cell acquisition procedure, i.e., time and frequency synchronization and detection of the cell ID. In this case, the frame offset may be a predefined value instead of being explicitly signaled by the network node 210, hence the value may be given by reading the standard specifications, and it may be selected, e.g., as zero or nine, first or last subframe in the frame.

With the arrangement described in embodiments herein, the number of used beam states of a TP, such as the network node 210 or TP 210, may be less than the maximal number N the current standard supports, since the offsets are signaled by SSS and/or PBCH. Moreover, the precoding weights that defined the beam state may be transparent to the wireless device 250, hence with this arrangement, any beam shapes, i.e., precoding weights, for PSS, SSS and PBCH may be implemented, which may be an advantage and gives flexibility to the wireless communications network 200. Hence, embodiments herein may provide a flexible way to deploy a 5G multi antenna 3D beamforming system, so it may be adapted to the scenario of the operation, and also to the actual implementation of the network node 210 or TP 210. An advantage of at least some of the embodiments herein may be that the PSS and SSS and/or PBCH are transmitted by the network node 210 in the same OFDM symbol, which may necessary when analog beamforming is performed at the transmitter side, since beamforming precoding weights may be only wideband in this case. For a digital implementation of the beamformer on the other hand, different beams may be used in different frequency bands. However, since implementations may be widely different among TP vendors and even for different products within a same vendor, the solution may not imply a certain TP implementation of beamforming, and this goal may be achieved with embodiments herein.

In a further network node 210 or TP 210 implementation embodiment, it may be possible to further relax the network node 210 or TP 210 implementation by not transmitting the PSS etc in every OFDM symbol. This may be useful in, e.g., the case switching time or precoder weight settling time is long. Hence, the same approach in embodiments herein may also enable this type of relaxed operation, where not every OFDM symbol may be used for transmitting by the network node 210, since the subframe and frame offsets may be acquired by the wireless device 250 individually, in each used OFDM symbol respectively. Whether every or as in the example below, every other OFDM symbol is transmitting PSS etc. is agnostic to the wireless device 250, since the wireless device 250 may simply fail to decode a PSS in OFDM symbols where no transmission by the network node 210 takes place.

Figure 7 depicts an example of a relaxed network node 210 or TP 210 implementation where only every other OFDM symbol is used by the network node 210, so that TP beamforming hardware may have sufficient time to switch beam. In this example shown here, only 7 beams may be scanned in one subframe.

The previous embodiments have described general aspects of the embodiments herein. The further embodiments below will describe enhancements that will relax the wireless device 250 implementation, in case the wireless device 250 has limited processing power.

In Figure 4, it was shown how the PSS and SSS may be separated by one slot. However, one, e.g., the network node 210 or TP 210, may separate the PSS and SSS even more, by several subframes, as long as the time between PSS and SSS transmissions by the network node 210 are known to the wireless device 250.

The PSS may be detected by the wireless device 250 in time domain, before Fast Fourier Transform (FFT) operation, using a down sampled signal if the PSS bandwidth is much less than the system bandwidth. However, the SSS and PBCH may be detected by the wireless device 250 in frequency domain, after FFT operation on the wideband signal, which may require some more processing power in the wireless device 250, and which then may require the wireless device 250 to buffer the whole wideband signal in each OFDM symbol until the PSS detector for a given OFDM symbol has finished the detection. So, it may be useful if the time between the PSS detection and the SSS/PBCH detection may be extended, so that buffering of many OFDM symbols is not required by the wireless device 250. The embodiment depicted in Figure 4 may allow this, since the network node 210 transmits the PSS and SSS in such way that there are 7 OFDM symbols between PSS and SSS. Hence, the wireless device 250 implementation may search for the PSS using the time domain signal, after successful PSS detection, it may prepare to perform an FFT operation of the OFDM symbol transmitted 7 OFDM symbols later, thereby relaxing the wireless device 250 implementation.

In a further wireless device 250 implementation embodiment, the time between PSS and SSS transmission by the network node 210 using the same beam is longer than the slot duration. The SSS may be transmitted by the network node 210 several subframes later, as long as this delay time is known by specification. The wireless device 250 may know the delay until the same OFDM symbol and beam state using the same PSS/SSS/PBCH transmission occurs again, and may thus wait until this delayed OFDM symbol, perform the FFT and detect SSS and PBCH. Alternatively, there may be a periodicity in the beam scanning, so that the wireless device 250 may know, by standard specification, that the same beam may be used again after a certain time, and this value may also depend on the maximum number of beam states N given in the standard specification. Hence, in this wireless device 250 implementation embodiment, the wireless device 250 may take advantage of the periodicity of the same signal transmission by the network node 210, and use of same beam state by the network node 210, and it may, in the first instance, use the time domain signal t● detect PSS and in a later, second instance, it may perform the FFT and detect SSS and PBCH.

In a further embodiment, the wireless device 250 may inform the network node 210 or TP 210 about which beam or beams was used in synchronizing to the network node 210 or TP 210. This may be useful in subsequent downlink transmissions from the network node 210 or TP 210 to the wireless device 250, for instance when transmitting additional system information blocks, configuration of the wireless device 250, or scheduling the uplink and downlink shared data channels.

According to the detailed description just provided with illustrative examples, embodiments of a method performed by the network node 210 for sending to the wireless device 250 a first synchronization signal and an associated information message, for synchronization of the wireless device 250 with the network node 210, will now be described with reference to the flowchart depicted depicted in **Figure 8**. Any of the details provided above in the illustrative examples, may be applicable to the description provided in regards to Figure 8, although they are not repeated here to facilitate the overview of the method. The network node 210 and the wireless device 250 operate in the wireless communications network 200, as stated earlier. Figure 8 depicts a flowchart of the actions that are or may be performed by the network node 210 in embodiments herein.

The method may comprise the following actions, which actions may as well be carried out in another suitable order than that described below.

Action 801

In order to allow the wireless device 250 to synchronize with the network node 210, that is in order to allow the wireless device 250 to obtain subframe timing and/or the frame timing in the signals sent by the network node 210, the network node 210 sends the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols, as illustrated in Figures 3-6. N, which was described earlier, is equal or larger than 2.

The first synchronization signal may provide the time structure on the smallest time scale up to a medium time scale, e.g., OFDM symbol timing, as well as the time position of the second synchronization signal.

The first synchronization signal may be a PSS, as described earlier, or an equivalent synchronization signal. The detailed description provided above, has used PSS as an illustrating example. However, any reference to PSS in the embodiments herein is understood to equally apply to the first synchronization signal.

In some embodiments, the network node 210 may perform the sending by utilizing beamforming.

In some embodiments, such as those utilizing beamforming, a different beam state, as described earlier, is used in at least two of the N OFDM symbols.

A different beam state may be used in each of the N OFDM symbols.

In some embodiments, the N OFDM symbols are non-consecutive OFDM symbols.

Action 802

Also in order to allow the wireless device 250 to synchronize with the network node 210, in this action, the network node 210, for each sending of the first synchronization signal, sends the associated information message at a pre-defined time and frequency position in an OFDM symbol, as illustrated in Figures 3-6. The pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal. The associated information message is associated with the first synchronization signal, that is, it comprises information that is associated with the first synchronization signal, for synchronization purposes. That is, the associated information message comprises information may allow the wireless device 250 to obtain subframe and/or frame timing.

In some embodiments, the associated information message comprises an associated second synchronization signal. The second synchronization signal may provide the time structure from a medium time scale up to a large time scale, e.g., subframe and/or frame timing. The second synchronization signal may be a SSS, as described earlier, or an equivalent synchronization signal. The detailed description provided above, has used SSS as an illustrating example. However, any reference to

SSS in the embodiments herein is understood to equally apply to the second synchronization signal.

The associated information message may comprise an associated PBCH. In these embodiments, the associated information message, may comprise the PBCH alone, or in addition to the second synchronization signal, e.g., the SSS.

In some embodiments, the associated PBCH further comprises associated system information.

In some embodiments, the network node 210 may perform the sending by utilizing beamforming. In these embodiments, wherein the first synchronization signal is sent in a beam state, the associated information message may be sent using the same beam state as the first synchronization signal associated with the associated information message.

In some embodiments, the associated information message is different in each OFDM symbol wherein the associated information message is sent.

The associated information message may comprise an index. An index may be a number that comprises a pre-defined unique mapping with the relative position of the OFDM symbol and the subframe and/or frame boundaries, which may allow the wireless device 250 to obtain the subframe and/or frame timing.

In some of these embodiments, the index is a sequence index, as described earlier.

In some of these embodiments, the subframe timing is obtainable by the wireless device 250 by detecting the index.

The sequence index may comprise an index representing a sequence out of a set of possible sequences. For example, in the embodiments wherein the associated information message comprises the associated second synchronization signal, the sequence index may be an index to one of the possible synchronization sequences which maps uniquely to at least a subframe offset.

In the embodiments wherein the associated information message comprises the associated PBCH, the index may be an explicit indication of the subframe offset or frame offset or both.

In some embodiments, the associated information message is the same in each OFDM symbol wherein the associated information message is sent within a subframe, and the associated information message is different in each subframe wherein the associated information message is sent within a transmitted frame. In these embodiments, wherein the associated information message comprises the index, a frame timing may be obtainable by the wireless device 250 by detecting the index.

In some embodiments wherein the associated information message comprises the associated SSS, and wherein the index is a sequence index, the subframe timing may be obtainable by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments wherein the associated information message comprises the associated SSS, and, wherein the index is the sequence index, the frame timing may be obtainable by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments, wherein the associated information message comprises the associated system information, the frame timing is obtainable by the wireless device 250 by detecting the index comprised in the associated system information.

Embodiments of a method performed by the wireless device 250 for detecting the first synchronization signal and the associated information message sent by the network node 210, for synchronization of the wireless device 250 with the network node 210, will now be described with reference to the flowchart depicted depicted in **Figure 9**. Any of the details provided above, may be applicable to the description provided in regards to Figure 9, although they are not repeated here to facilitate the overview of the method. The network node 210 and the wireless device 250 operate in the wireless communications network 200, as stated earlier. Figure 9 depicts a flowchart of the actions that are or may be performed by the wireless device 250 in embodiments herein.

The method may comprise the following actions, which actions may as well be carried out in another suitable order than that described below. In some embodiments, all the actions may be carried out, whereas in other embodiments only some action/s may be carried out.

Action 901

As a first step for the wireless device 250 to obtain subframe timing and/or the frame timing in the signals sent by the network node 210, that is, in order to synchronize with the network node 210, the wireless device 250 detects the first synchronization signal. As described earlier, the first synchronization signal has been sent by the network node 210 in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2.

As discussed above, in some embodiments, the network node 210 may have performed the sending utilizing beamforming.

Also as stated earlier, the first synchronization signal may be a PSS.

In some embodiments, this action may be implemented when for example, the wireless device 250 is using a procedure similar to LTE cell search and is simultaneously searching over different TP beams.

Action 902

To ensure good synchronization performance, in some embodiments, the wireless device 250 may discard detected OFDM symbols sent by the network node 210, as described earlier. This may happen, where detection of the first synchronization signal in the discarded detected OFDM symbols is poor according to a threshold. For example, this threshold may be based on the estimated signal to noise ratio of the detected OFDM symbol. That is, the wireless device 250 may not take the discarded OFDM symbols into consideration to obtain subframe or frame timing.

Action 903

The wireless device 250 detects the associated information message at the pre-defined time and frequency position. The pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal. The associated information message corresponds to that described above. Thus, the associated information message is associated with the first synchronization signal.

Also was mentioned above, in some embodiments, the associated information message comprises the associated second synchronization signal. The second synchronization signal may be an SSS.

Detecting the associated information message may comprise matching a sequence of the detected associated information message to one of a set of possible information message sequences. As stated earlier, this set of possible information message sequences may be the SSS specified in LTE.

In some embodiments, the associated information message comprises the associated PBCH, as mentioned above. In some of these embodiments, the associated PBCH further comprises the associated system information.

The associated information message comprises the index.

In some of these embodiments, the index is the sequence index.

In some embodiments, the sequence index comprises the index representing the sequence out of the set of possible sequences.

Action 904

The wireless device 250 obtains the subframe timing and/or the frame timing by detecting the index comprised in the associated information message. This is because the index comprises a pre-defined unique mapping with the relative position of the OFDM symbol and the subframe and/or frame boundaries.

In some embodiments, the associated information message is different in each OFDM symbol wherein the associated information message is sent by the network node 210. In these embodiments, the subframe timing may be obtained by the wireless device 250 by detecting the index.

In some embodiments, the associated information message is the same in each OFDM symbol wherein the associated information message is sent by the network node 210 within a subframe, and the associated information message is different in each subframe wherein the associated information message is sent by the network node 210 within a transmitted frame. In these embodiments, the frame timing may be obtained by the wireless device 250 by detecting the index.

In some embodiments, the associated information message comprises the associated SSS. In these embodiments, wherein the index is the sequence index, the subframe timing may be obtained by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments, the associated information message comprises the associated SSS. In these embodiments, wherein the index is the sequence index, the frame timing may be obtained by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments, the associated information message comprises the associated system information, and the frame timing is obtained may be the wireless device 250 by detecting the index comprised in the associated system information.

Action 905

In some embodiments wherein the network node 210 has performed the sending of the first synchronization signal and the associated information message utilizing beamforming, the wireless device 250 may send a message to the network node 210. The message may comprise information about which beam, of the beams beamformed by the network node 210 to send the first synchronization signal and the associated information message, was used by the wireless device 250 for synchronization. For example, the time and frequency position of the transmitted message may be used to implicitly communicate to the network node 210 which beam was used by the wireless device 250.

In some embodiments, the information in the message may comprise a beam state index of the beam that was used by the wireless device 250 for synchronization.

The wireless device 250 may send this message, for example, as a random access preamble comprising a sequence and/or time frequency resource determined by the index of the beam state that was used.

Embodiments herein may thus provide an approach to address the problems mentioned above, by the network node 210 repeatedly transmitting the same e.g., PSS in a scanned manner, in a new beam in each OFDM symbol. The instantaneous beam, used in a given OFDM symbol, may be unknown to the wireless device 250, who may perform a blind search after the e.g., PSS in time domain in order to acquire the OFDM symbol timing, which may be a prerequisite to transform the received signal into frequency domain, before further receiver processing. After detecting the PSS, the wireless device 250 may find the SSS and e.g., PBCH in a position relative to the PSS. Different from the PSS, the SSS and/or PBCH may be different in each OFDM symbol. By this arrangement, the wireless device 250 may acquire the symbol offset, i.e., the subframe offset, as used herein, as well as the frame offset in the wireless communications network 200. In some embodiments, this may be a beamformed network.

Figure 10 depicts, a flowchart of an example of the method performed by the wireless device 250, according to some embodiments herein, and as just described in reference to Figure 9. The numbers on the right side of the Figure indicate the correspondence to the actions described in Figure 9. In the figure, the wireless device 250 is represented as "UE". In Figure 10, subframe offset, as used herein, is represented as "symbol offset (subframe boundary)". In this particular example, the first synchronization signal is a PSS, the associated information message comprises a second synchronization signal, which is a SSS and the PBCH, and the network node 210 has performed the sending utilizing beamfoming. A beam is represented in the Figure as being identified by "Bi".

Figure 11 and **Figure 12** depict schematic diagrams of at least part of methods in the network node 210 and the wireless device 250, according to some embodiments herein, and as just described in reference to some actions in Figures 8 and 9, respectively. The numbers on the left and right side of the Figure indicate the correspondence to the actions described in Figures 8 and 9, respectively. In both figures, the network node 210 or TP 210 is represented as "Network/Transmission Point", and the wireless device 250 is represented as "UE". Also in both figures, the index, which in this case is a sequence index, is represented as "index j". Figure 11 depicts a schematic diagram describing some actions of one of the embodiments described herein, where the SSS determines the subframe and frame timing. Note that the PSS, SSS and PBCH not necessarily need to be transmitted in the same OFDM symbol. Note also that in this embodiment, the wireless device 250, may accumulate PBCH across several OFDM symbols since the PBCH remains the same in each OFDM symbol. In the particular examples of Figures 11 and 12, the first synchronization signal is a PSS, the associated information message comprises a second synchronization signal, which is a SSS, and the PBCH, and the network node 210 has performed the sending utilizing beamforming. The beam state index is represented in both Figures as being identified by "Bi".

Figure 12 depicts a schematic diagram describing some actions of one of the embodiments described herein, where the SSS determines the subframe timing and the PBCH contains information used to determine frame timing. Note that the PSS, SSS and PBCH not necessarily need to be transmitted in the same OFDM symbol. In this figure, the index is represented as "index j" for the sequence index in the SSS, and it is represented as "k" for index in the PBCH.

To perform the method actions described above in relation to Figures 8, 11 and 12, the network node 210 is configured to send, to the wireless device 250, the first synchronization signal and the associated information message, for synchronization of the wireless device 250 with the network node 210. The network node 210 comprises the following arrangement depicted in **Figure 13**. As already mentioned, in some embodiments, the network node 210 may be configured to send utilizing beamforming. The network node 210 and the wireless device 250 are configured to operate in the wireless communications network 200.

The detailed description of some of the following corresponds to the same references provided above, in relation to the actions described for the network node 210, and will thus not be repeated here.

The network node 210 may be configured to send the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2.

This may be performed by a **sending module 1301** in the network node 210.

In some embodiments, for each sending of the first synchronization signal, the network node 210 is further configured to send the associated information message at the pre-defined time and frequency position in an OFDM symbol. The pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal. The associated information message is associated with the first synchronization signal.

This may be also be performed by the sending module sending 1301.

The first synchronization signal may be a PSS.

In some embodiments, the associated information message comprises the associated second synchronization signal. The second synchronization signal may be a SSS.

In some embodiments, the associated information message comprises the associated PBCH.

In some embodiments, the network node 210 is further configured to use a different beam state in at least two of the N OFDM symbols.

This may be also be performed by the sending module sending 1301.

In some embodiments, the network node 210 is further configured to use a different beam state is used in each of the N OFDM symbols.

This may be also be performed by the sending module sending 1301.

In some embodiments, the network node 210 is further configured to send the first synchronization signal in a beam state, and to send the associated information message using the same beam state as the first synchronization signal associated with the associated information message.

This may be also be performed by the sending module sending 1301.

In some embodiments, the associated PBCH further comprises the associated system information.

In some embodiments, the associated information message is different in each OFDM symbol wherein the associated information message is configured to be sent by network node 210, the associated information message comprises the index, and the subframe timing is obtainable by the wireless device 250 by detecting the index.

In some embodiments, the associated information message is the same in each OFDM symbol wherein the associated information message is configured to be sent by the network node 210 within a subframe, the associated information message is different in each subframe wherein the associated information message is configured to be sent by the network node 210 within a transmitted frame, the associated information message comprises the index, and the frame timing is obtainable by the wireless device 250 by detecting the index.

In some embodiments, the associated information message comprises the associated SSS, the index is the sequence index, and the subframe timing is obtainable by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments, the associated information message comprises the associated SSS, the index is the sequence index, and the frame timing is obtainable by the wireless device 250 by detecting the sequence index comprised in the associated SSS.

In some embodiments, the associated information message comprises the associated system information, and the frame timing is obtainable by the wireless device 250 by detecting the index comprised in the associated system information.

In some embodiments, the sequence index comprises the index representing a sequence out of the set of possible sequences.

In some embodiments, the N OFDM symbols are non- consecutive OFDM symbols.

The embodiments herein for sending, e.g., utilizing beamforming, to the wireless device 250 the first synchronization signal and the associated information message, for synchronization of the wireless device 250 with the network node 210 may be implemented through one or more processors, such as the **processing module 1302** in the network node 210 depicted in Figure 13, together with computer program code for performing the functions and actions of the embodiments herein. The program code mentioned above may also be provided as a computer program product, for instance in the form of a data carrier carrying computer program code for performing the embodiments herein when being loaded into the in the network node 210. One such carrier may be in the form of a CD ROM disc. It may be however feasible with other data carriers such as a memory stick. The computer program code may furthermore be provided as pure program code on a server and downloaded to the network node 210.

The network node 210 may further comprise a **memory module 1303** comprising one or more memory units. The memory module 1303 may be arranged to be used to store data in relation to applications to perform the methods herein when being executed in the network node 210. Memory module 1303 may be in communication with the processing module 1302. Any of the other information processed by the processing module 1302 may also be stored in the memory module 1303.

In some embodiments, information may be received, for example, from the wireless device 250, through a **receiving port 1304**. In some embodiments, the receiving port 1304 may be, for example, connected to the one or more antennas in the network node 210. In other embodiments, the network node 210 may receive information from another structure in the wireless communications network 200 through the receiving port 1304. Since the receiving port 1304 may be in communication with the processing module 1302, the receiving port 1304 may then send the received information to the processing module 1302. The receiving port 1304 may also be configured to receive other information.

The information processed by the processing module 1302 in relation to the embodiments of method herein may be stored in the memory module 1303 which, as stated earlier, may be in communication with the processing module 1302 and the receiving port 1304.

The processing module 1302 may be further configured to transmit or send information to the wireless device 250 or another node in the wireless communications network 200, through **a sending port 1305**, which may be in communication with the processing module 1302, and the memory module 1303.

Those skilled in the art will also appreciate that the module 1301 described above may refer to a combination of analog and digital modules, and/or one or more processors configured with software and/or firmware, e.g., stored in memory, that, when executed by the one or more processors such as the processing module 1302, perform as described above. One or more of these processors, as well as the other digital hardware, may be included in a single application-specific integrated circuit (ASIC), or several processors and various digital hardware may be distributed among several separate components, whether individually packaged or assembled into a system-on-a-chip (SoC).

Thus, the methods according to the embodiments described herein for the network node 210 are respectively implemented by means of a computer program product, comprising instructions, i.e., software code portions, which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the network node 210. The computer program product may be stored on a computer-readable storage medium. The computer-readable storage medium, having stored thereon the computer program, may comprise instructions which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the network node 210. In some embodiments, the computer-readable storage medium may be a non-transitory computer-readable storage medium.

To perform the method actions described above in relation to Figures 9, 10, 11 and 12, the wireless device 250 is configured to detect the first synchronization signal and the associated information message configured to be sent by the network node 210, for synchronization of the wireless device 250 with the network node 210. The wireless device 250 comprises the following arrangement depicted in **Figure 14**. In some embodiments, the network node 210 may have performed the sending utilizing beamforming. The network node 210 and the wireless device 250 are configured to operate in the wireless communications network 200. The detailed description of some of the following corresponds to the same references provided above, in relation to the actions described for the wireless device 250, and will thus not be repeated here.

The wireless device 250 may be configured to detect the first synchronization signal. The first synchronization signal is configured to have been sent by the network node 210 in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols. N is equal or larger than 2.

This may be performed by a **detecting module 1401** in the wireless device 250.

In some embodiments, the wireless device 250 is further configured to detect the associated information message at the pre-defined time and frequency position. The pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal. The associated information message is associated with the first synchronization signal.

This may be also be performed by the detecting module 1401.

The first synchronization signal may be a PSS.

In some embodiments, the associated information message comprises the associated second synchronization signal. The second synchronization signal may be a SSS.

In some embodiments, to detect the associated information message comprises to match the sequence of the detected associated information message to the one of the set of possible information message sequences.

In some embodiments, the associated information message comprises the associated PBCH.

In some embodiments, the associated PBCH further comprises associated system information.

The associated information message comprises the index.

The wireless device 250 may be configured to obtain the subframe timing and/or the frame timing by detecting the index comprised in the associated information message.

This may be performed by **an obtaining module 1402** in the wireless device 250.

In some embodiments, the associated information message is different in each OFDM symbol wherein the associated information message is configured to be sent by the network node 210, the associated information message comprises the index, and the wireless device 250 is further configured to obtain the subframe timing by detecting the index.

This may be also be performed by the obtaining module 1402.

In some embodiments, the associated information message is the same in each OFDM symbol wherein the associated information message is configured to be sent by the network node 210 within a subframe, the associated information message is different in each subframe wherein the associated information message is configured to be sent by the network node 210 within a transmitted frame, the associated information message comprises the index, and the wireless device 250 is further configured to obtain the frame timing by detecting the index.

This may be also be performed by the obtaining module 1402.

In some embodiments, the associated information message comprises the associated SSS, the index is the sequence index, and the wireless device 250 is further configured to obtain the frame timing by detecting the sequence index comprised in the associated SSS.

This may be also be performed by the obtaining module 1402.

In some embodiments, the associated information message comprises the associated system information, and the wireless device 250 is further configured to obtain the frame timing by detecting the index comprised in the associated system information.

This may be also be performed by the obtaining module 1402.

In some embodiments, the sequence index comprises the index representing the sequence out of the set of possible sequences.

In some embodiments, the wireless device 250 may be configured to discard detected OFDM symbols configured to be sent by the network node 210, wherein detection of the first synchronization signal in the discarded detected OFDM symbols is poor according to the threshold.

This may be performed by a **discarding module 1403** in the wireless device 250.

In some embodiments, the wireless device 250 may be configured to send the message to the network node 210, the message comprising the information about which beam of the beams configured to be beamformed by the network node 210 to send the first synchronization signal and the associated information message was used by the wireless device 250 for synchronization.

This may be performed by a **sending module 1404** in the wireless device 250.

The embodiments herein for detecting the first synchronization signal and the associated information message sent by the network node 210 e.g., utilizing beamforming, for synchronization of the wireless device 250 with the network node 210 may be implemented through one or more processors, such as the **processing module 1405** in the wireless device 250 depicted in Figure 14, together with computer program code for performing the functions and actions of the embodiments herein. The program code mentioned above may also be provided as a computer program product, for instance in the form of a data carrier carrying computer program code for performing the embodiments herein when being loaded into the in the wireless device 250. One such carrier may be in the form of a CD ROM disc. It may be however feasible with other data carriers such as a memory stick. The computer program code may furthermore be provided as pure program code on a server and downloaded to the wireless device 250.

The wireless device 250 may further comprise a **memory module 1406** comprising one or more memory units. The memory module 1406 may be arranged to be used to store data in relation to applications to perform the methods herein when being executed in the wireless device 250. Memory module 1406 may be in communication with the processing module 1405. Any of the other information processed by the processing module 1405 may also be stored in the memory module 1406.

In some embodiments, information may be received from, for example the network node 210, through a **receiving port 1407**. In some embodiments, the receiving port 1407 may be, for example, connected to the one or more antennas in the wireless device 250. In other embodiments, the wireless device 250 may receive information from another structure in the wireless communications network 200 through the receiving port 1407. Since the receiving port 1407 may be in communication with the processing module 1405, the receiving port 1407 may then send the received information to the processing module 1405. The receiving port 1407 may also be configured to receive other information.

The information processed by the processing module 1405 in relation to the embodiments of method herein may be stored in the memory module 1406 which, as stated earlier, may be in communication with the processing module 1405 and the receiving port 1407.

The processing module 1405 may be further configured to transmit or send information to the network node 210, through **a sending port 1408**, which may be in communication with the processing module 1405, and the memory module 1406.

Those skilled in the art will also appreciate that the different modules 1401-1404 described above may refer to a combination of analog and digital modules, and/or one or more processors configured with software and/or firmware, e.g., stored in memory, that, when executed by the one or more processors such as the processing module 1405, perform as described above. One or more of these processors, as well as the other digital hardware, may be included in a single application-specific integrated circuit (ASIC), or several processors and various digital hardware may be distributed among several separate components, whether individually packaged or assembled into a system-on-a-chip (SoC).

Thus, the methods according to the embodiments described herein for the wireless device 250 are respectively implemented by means of a computer program product, comprising instructions, i.e., software code portions, which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the wireless device 250. The computer program product may be stored on a computer-readable storage medium. The computer-readable storage medium, having stored thereon the computer program, may comprise instructions which, when executed on at least one processor, cause the at least one processor to carry out the actions described herein, as performed by the wireless device 250. In some embodiments, the computer-readable storage medium may be a non-transitory computer-readable storage medium.

When using the word "comprise" or "comprising" it shall be interpreted as non-limiting, i.e. meaning "consist at least of".

The embodiments herein are not limited to the above described preferred embodiments. Various alternatives, modifications and equivalents may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention.

CLAIMS:

1. A method performed by a network node (210) for sending to a wireless device (250) a first synchronization signal and an associated information message, for synchronization of the wireless device (250) with the network node (210), the network node (210) and the wireless device (250) operating in a wireless communications network (200), the method comprising:

   sending (801) the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols, wherein N is equal or larger than 2, and,

   for each sending of the first synchronization signal, *sending* (802) an associated information message at a pre-defined time and frequency position in an OFDM symbol, which pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal, and which associated information message is associated with the first synchronization signal.

2. The method of claim 1, wherein the first synchronization signal is a Primary Synchronization Signal, PSS, and wherein the associated information message comprises an associated second synchronization signal, wherein the second synchronization signal is a Secondary Synchronization Signal, SSS.

3. The method of any of claims 1-2, wherein the associated information message comprises an associated Physical Broadcast CHannel, PBCH, wherein the associated PBCH further comprises associated system information.

4. The method of any of claims 1-3, wherein the first synchronization signal is sent in a beam state, and wherein the associated information message is sent using the same beam state as the first synchronization signal associated with the associated information message.

5. The method of any of claims 1-4, wherein the associated information message is different in each OFDM symbol wherein the associated information message is sent, wherein the associated information message comprises an index, and

wherein a subframe timing is obtainable by the wireless device (250) by detecting the index.

6. The method of any of claims 1-4, wherein the associated information message is the same in each OFDM symbol wherein the associated information message is sent within a subframe, and wherein the associated information message is different in each subframe wherein the associated information message is sent within a transmitted frame, wherein the associated information message comprises an index, and wherein a frame timing is obtainable by the wireless device (250) by detecting the index.

7. The method of claims 2 and 5, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the subframe timing is obtainable by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

8. The method of any of claims 2 and 6, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the frame timing is obtainable by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

9. A method performed by a wireless device (250) for detecting a first synchronization signal and an associated information message sent by a network node (210) for synchronization of the wireless device (250) with the network node (210), the network node (210) and the wireless device (250) operating in a wireless communications network (200), the method comprising:

detecting (901) the first synchronization signal, wherein the first synchronization signal has been sent by the network node (210) in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols, wherein N is equal or larger than 2, and,

detecting (903) the associated information message at a pre-defined time and frequency position, which pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal, which associated information message is associated with the first synchronization signal; and *obtaining* (904) subframe timing and/or frame timing by detecting an index comprised in the associated information message.

10. The method of claim 9, wherein the first synchronization signal is a Primary Synchronization Signal, PSS, and wherein the associated information message comprises an associated second synchronization signal, wherein the second synchronization signal is a Secondary Synchronization Signal, SSS.

11. The method of claim 10, wherein detecting the associated information message comprises matching a sequence of the detected associated information message to one of a set of possible information message sequences.

12. The method of any of any of claims 9-11, wherein the associated information message comprises an associated Physical Broadcast CHannel, PBCH, wherein the associated PBCH further comprises associated system information.

13. The method of any of claims 9-12, wherein the associated information message is different in each OFDM symbol wherein the associated information message is sent by the network node (210), wherein the associated information message comprises an index, and wherein a subframe timing is obtained by the wireless device (250) by detecting the index.

14. The method of any of claims 9-12, wherein the associated information message is the same in each OFDM symbol wherein the associated information message is sent by the network node (210) within a subframe, and wherein the associated information message is different in each subframe wherein the associated information message is sent by the network node (210) within a transmitted frame, wherein the associated information message comprises an index, and wherein a frame timing is obtained by the wireless device (250) by detecting the index.

15. The method of claims 11 and 13, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the subframe timing is obtained by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

16. The method of any of claims 11 and 14, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index,

and wherein the frame timing is obtained by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

17. The method of claims 12 and 13 and 15, wherein the associated information message comprises the associated system information, and wherein the frame timing is obtained by the wireless device (250) by detecting the index comprised in the associated system information.

18. A network node (210) configured to send to a wireless device (250) a first synchronization signal and an associated information message, for synchronization of the wireless device (250) with the network node (210), the network node (210) and the wireless device (250) being configured to operate in a wireless communications network (200), the network node (210) being configured to:

send the first synchronization signal in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols, wherein N is equal or larger than 2, and,

for each sending of the first synchronization signal, send an associated information message at a pre-defined time and frequency position in an OFDM symbol, which pre-defined time and frequency position is relative to the time and frequency position of the first synchronization signal, and which associated information message is associated with the first synchronization signal.

19. The network node (210) of claim 18, wherein the first synchronization signal is a Primary Synchronization Signal, PSS, and wherein the associated information message comprises an associated second synchronization signal, wherein the second synchronization signal is a Secondary Synchronization Signal, SSS.

20. The network node (210) of any of claims 18-19, wherein the associated information message comprises an associated Physical Broadcast CHannel, PBCH, wherein the associated PBCH further comprises associated system information.

21. The network node (210) of any of claims 18-20, wherein the network node (210) is further configured to send the first synchronization signal in a beam state, and to send the associated information message using the same beam state as the first synchronization signal associated with the associated information message.

22. The network node (210) of any of claims 18-21, wherein the associated information message is different in each OFDM symbol wherein the associated information message is configured to be sent by the network node (210), wherein the associated information message comprises an index, and wherein a subframe timing is obtainable by the wireless device (250) by detecting the index.

23. The network node (210) of any of claims 18-21, wherein the associated information message is the same in each OFDM symbol wherein the associated information message is configured to be sent by the network node (210) within a subframe, and wherein the associated information message is different in each subframe wherein the associated information message is configured to be sent by the network node (210) within a transmitted frame, wherein the associated information message comprises an index, and wherein a frame timing is obtainable by the wireless device (250) by detecting the index.

24. The network node (210) of claims 19 and 22, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the subframe timing is obtainable by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

25. The network node (210) of any of claims 19 and 23, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the frame timing is obtainable by the wireless device (250) by detecting the sequence index comprised in the associated SSS.

26. A wireless device (250) configured to detect a first synchronization signal and an associated information message configured to be sent by a network node (210), for synchronization of the wireless device (250) with the network node (210), the network node (210) and the wireless device (250) being configured to operate in a wireless communications network (200), the wireless device (250) being configured to:

detect the first synchronization signal, wherein the first synchronization signal is configured to have been sent by the network node (210) in N OFDM symbols within a subframe, at least once in a time and frequency position in every one of the N OFDM symbols, wherein N is equal or larger than 2, and, detect the associated information message at a pre-defined time and frequency position, which pre-defined time and frequency position is relative to the time and frequency position of the detected first synchronization signal, and which associated information message is associated with the first synchronization signal; and

obtain subframe timing and/or frame timing by detecting an index comprised in the associated information message.

27. The wireless device (250) of claim 26, wherein the first synchronization signal is a Primary Synchronization Signal, PSS, and wherein the associated information message comprises an associated second synchronization signal, wherein the second synchronization signal is a Secondary Synchronization Signal, SSS.

28. The wireless device (250) of claim 27, wherein to detect the associated information message comprises to match a sequence of the detected associated information message to one of a set of possible information message sequences.

29. The wireless device (250) of any of claims 26-28, wherein the associated information message comprises an associated Physical Broadcast CHannel, PBCH, wherein the associated PBCH further comprises associated system information.

30. The wireless device (250) of any of claims 26-29, wherein the associated information message is different in each OFDM symbol wherein the associated information message is configured to be sent by the network node (210), wherein the associated information message comprises an index, and wherein the wireless device (250) is further configured to obtain a subframe timing by detecting the index.

31. The wireless device (250) of any of claims 26-29, wherein the associated information message is the same in each OFDM symbol wherein the associated information message is configured to be sent by the network node (210) within a subframe, and wherein the associated information message is different in each subframe wherein the associated information message is configured to be sent by the network node (210) within a transmitted frame, wherein the associated

information message comprises an index, and wherein the wireless device (250) is further configured to obtain a frame timing by detecting the index.

32. The wireless device (250) of claims 27 and 30, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the wireless device (250) is further configured to obtain the subframe timing by detecting the sequence index comprised in the associated SSS.

33. The wireless device (250) of any of claims 27 and 31, wherein the associated information message comprises the associated SSS, wherein the index is a sequence index, and wherein the wireless device (250) is further configured to obtain the frame timing by detecting the sequence index comprised in the associated SSS.

34. The wireless device (250) of claims 29 and 31 and 33, wherein the associated information message comprises the associated system infomation, and wherein the wireless device (250) is further configured to obtain the frame timing by detecting the index comprised in the associated system information.

35. Computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 1 to 8.

36. A computer-readable storage medium, having stored thereon a computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 1 to 8.

37. Computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 9 to 17.

38. A computer-readable storage medium, having stored thereon a computer program, comprising instructions which, when executed on at least one processor, cause the at least one processor to carry out the method according to any one of claims 9 to 17.

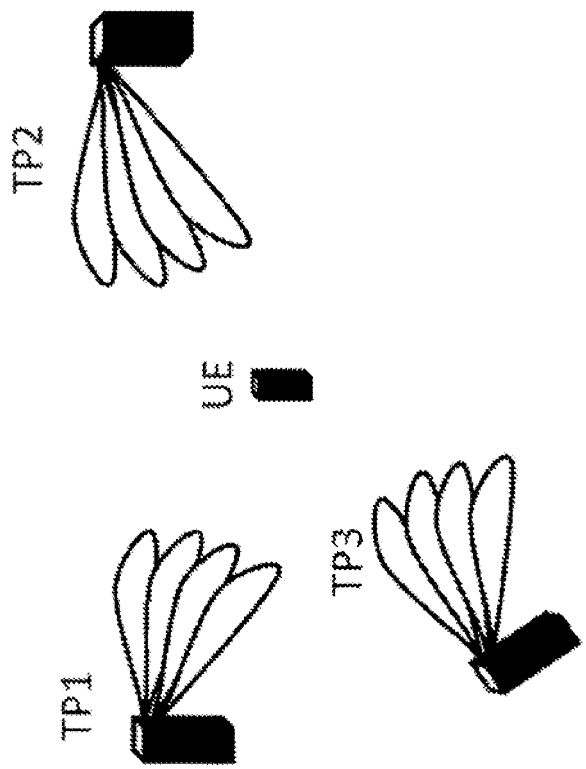

Figure 1

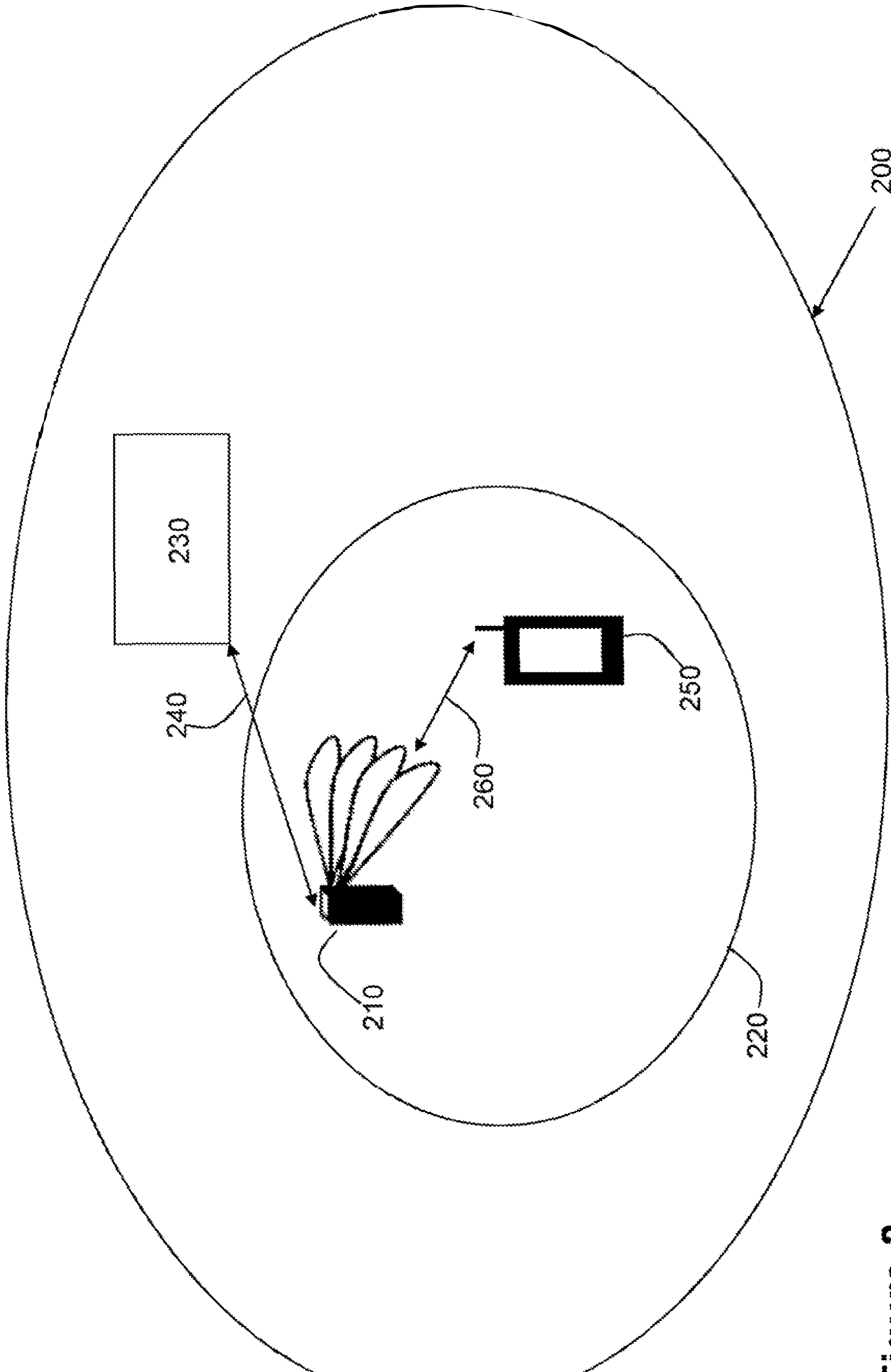

Figure 2

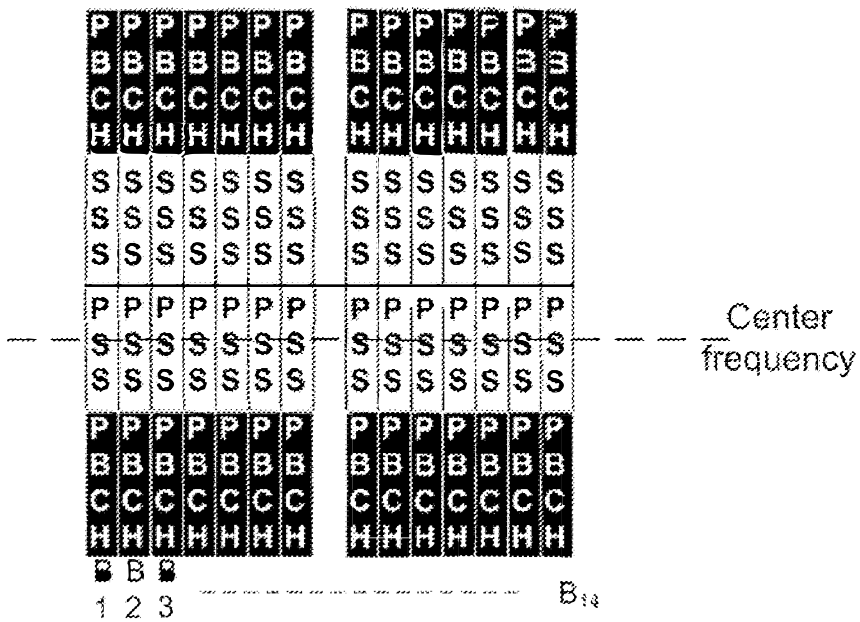

Figure 3

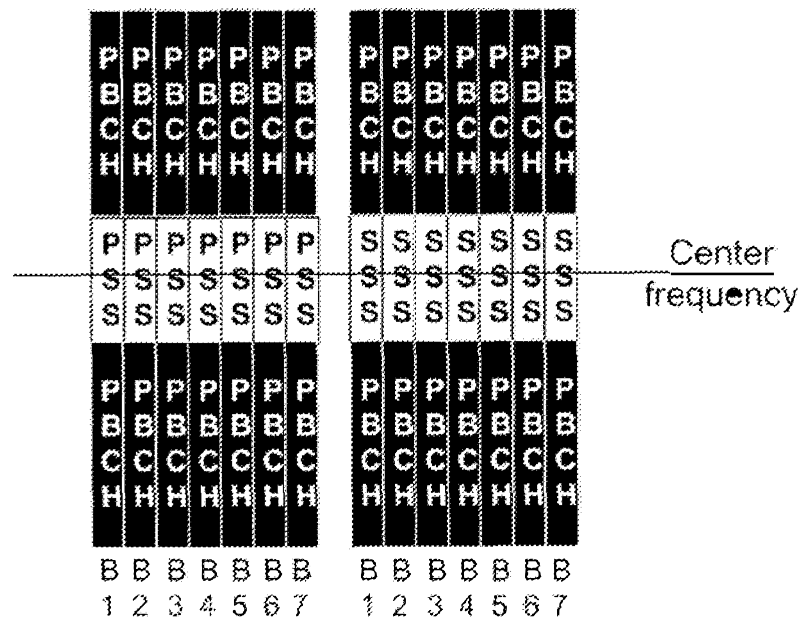

Figure 4

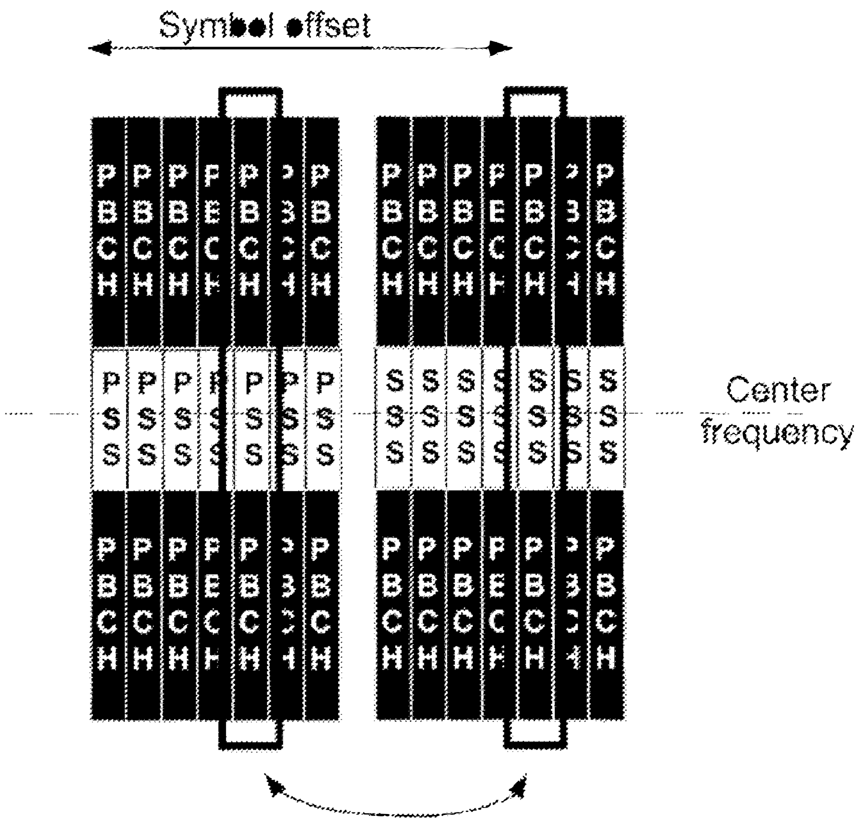

Figure 5

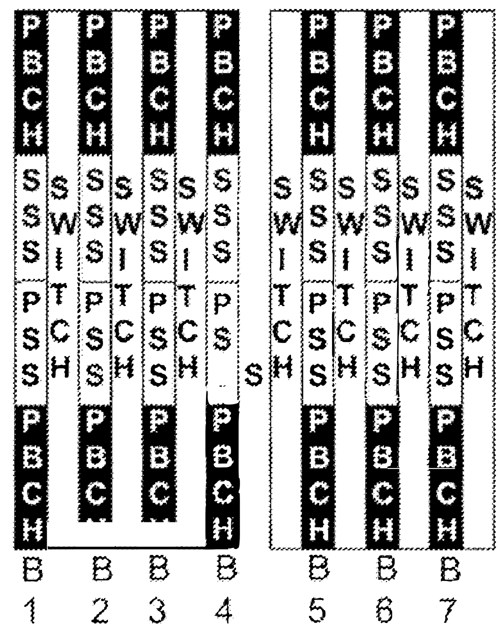

Figure 7

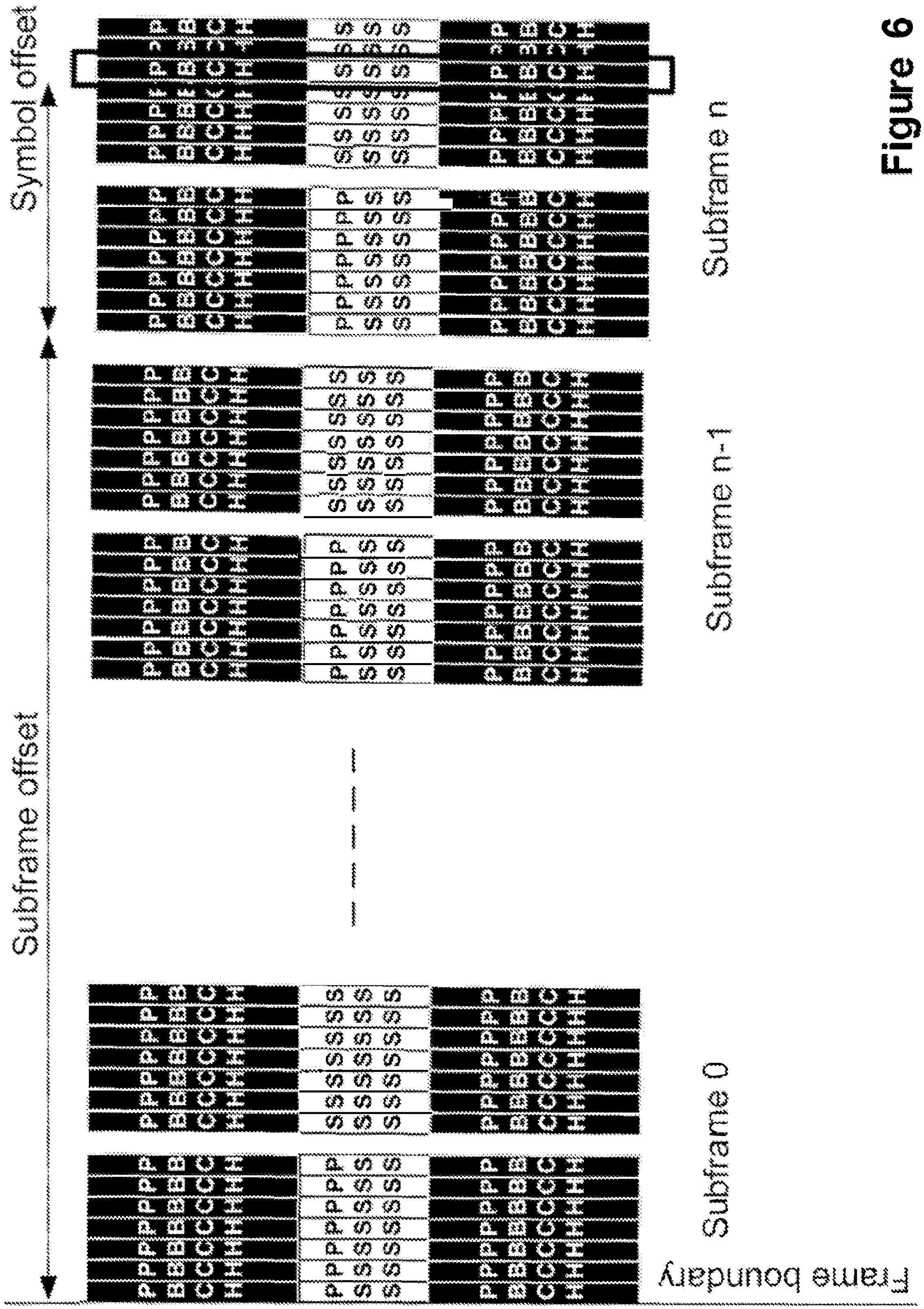
Symbol offset
Subframe offset
Subframe n
Subframe n-1
Subframe 0
Frame boundary

Figure 6

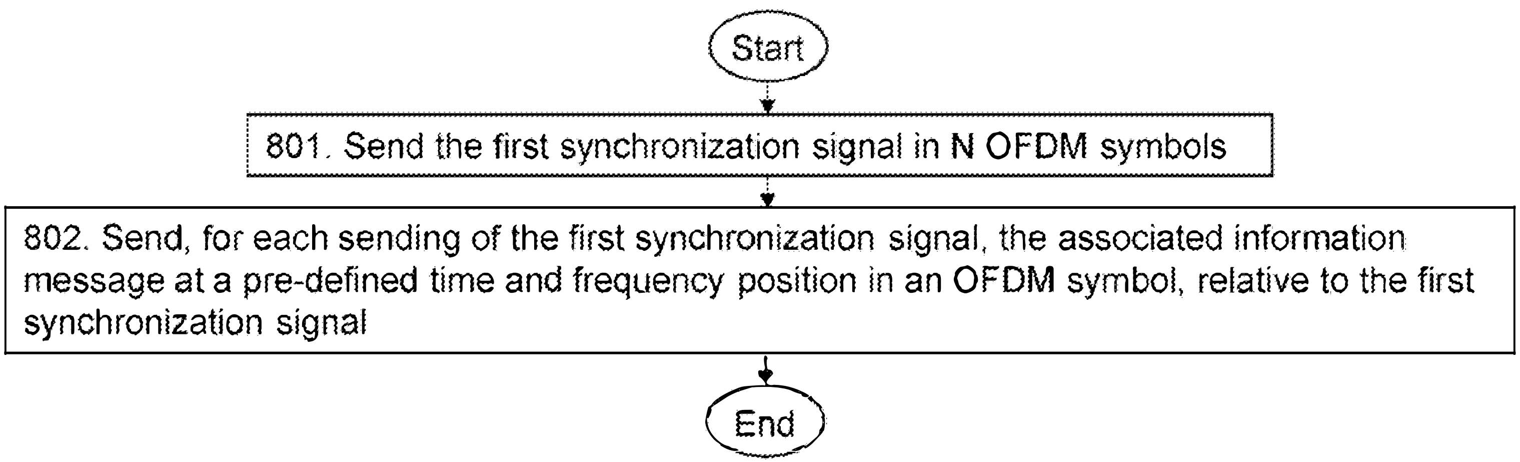
Start
801. Send the first synchronization signal in N OFDM symbols
802. Send, for each sending of the first synchronization signal, the associated information message at a pre-defined time and frequency position in an OFDM symbol, relative to the first synchronization signal
End

Figure 8

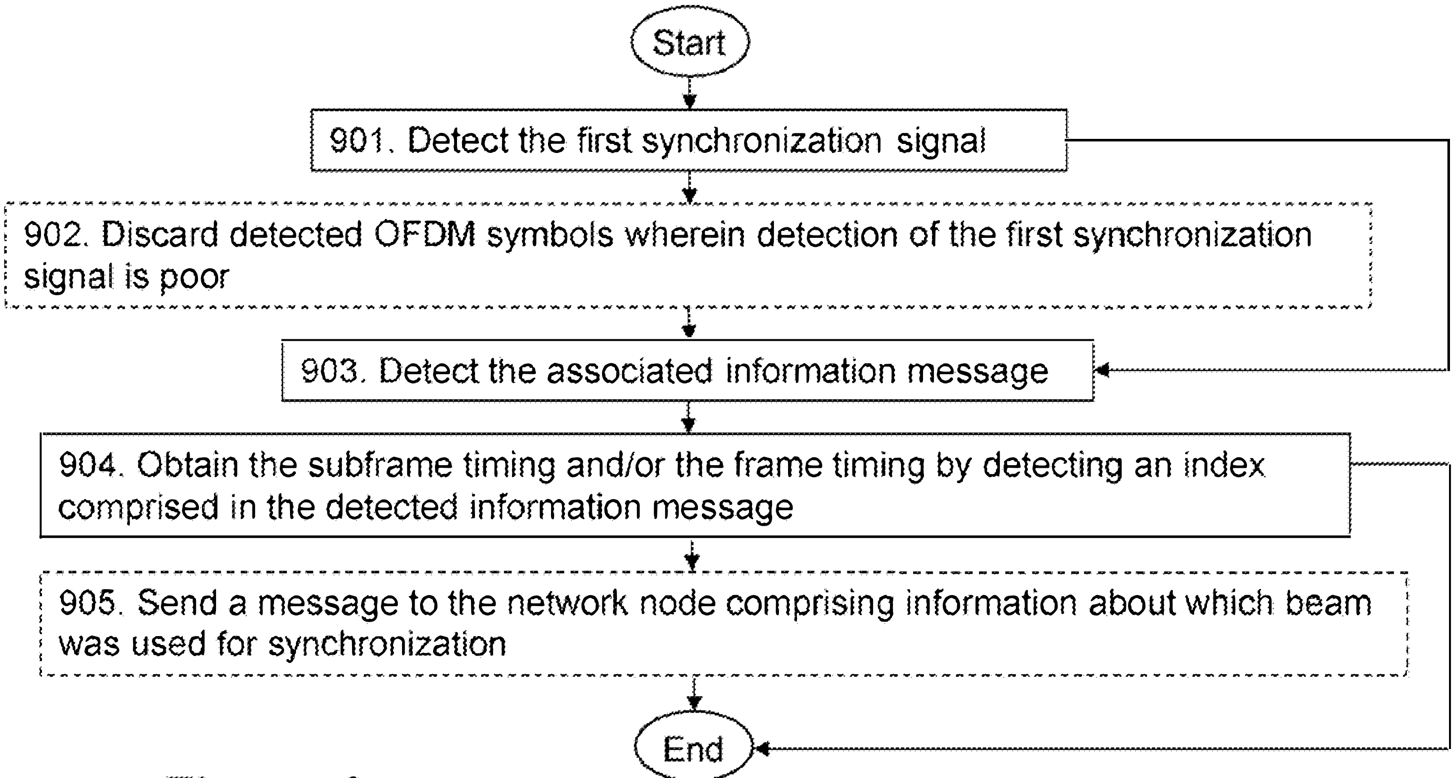
Start
901. Detect the first synchronization signal
902. Discard detected OFDM symbols wherein detection of the first synchronization signal is poor
903. Detect the associated information message
904. Obtain the subframe timing and/or the frame timing by detecting an index comprised in the detected information message
905. Send a message to the network node comprising information about which beam was used for synchronization
End

Figure 9

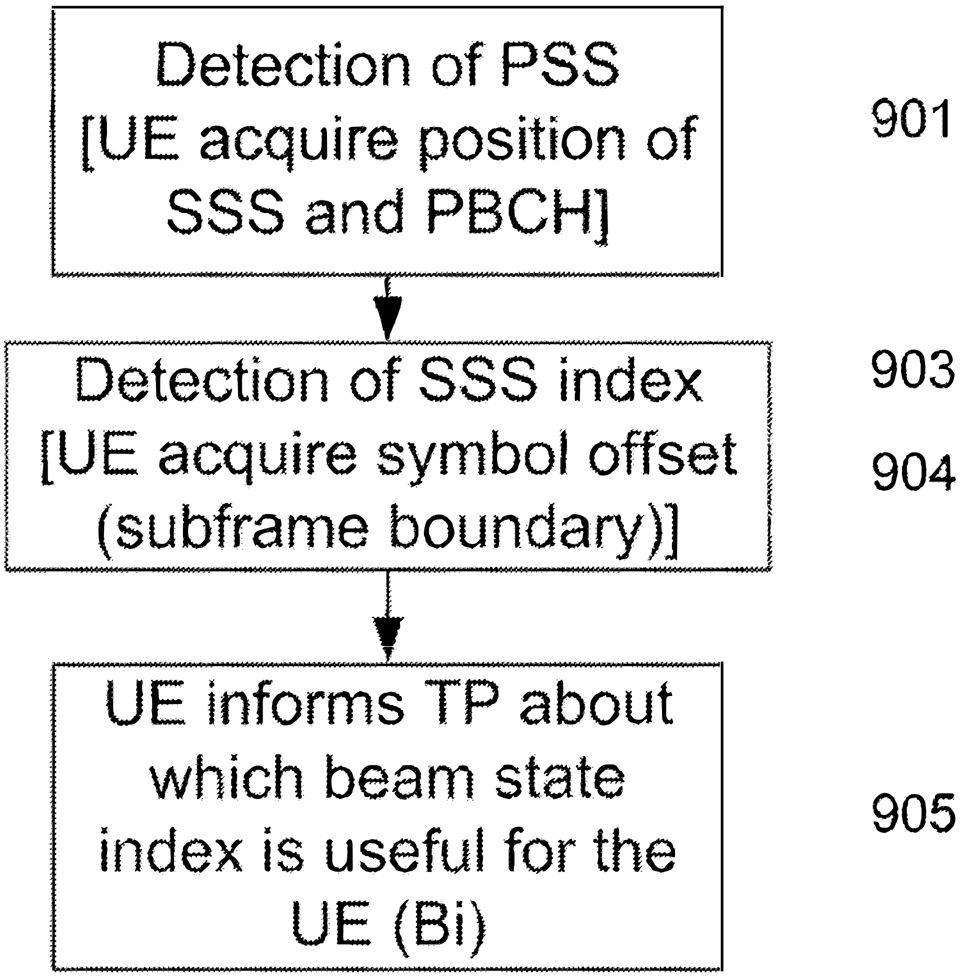
Detection of PSS [UE acquire position of SSS and PBCH]
901
Detection of SSS index [UE acquire symbol offset (subframe boundary)]
903
904
UE informs TP about which beam state index is useful for the UE (Bi)
905

Figure 10

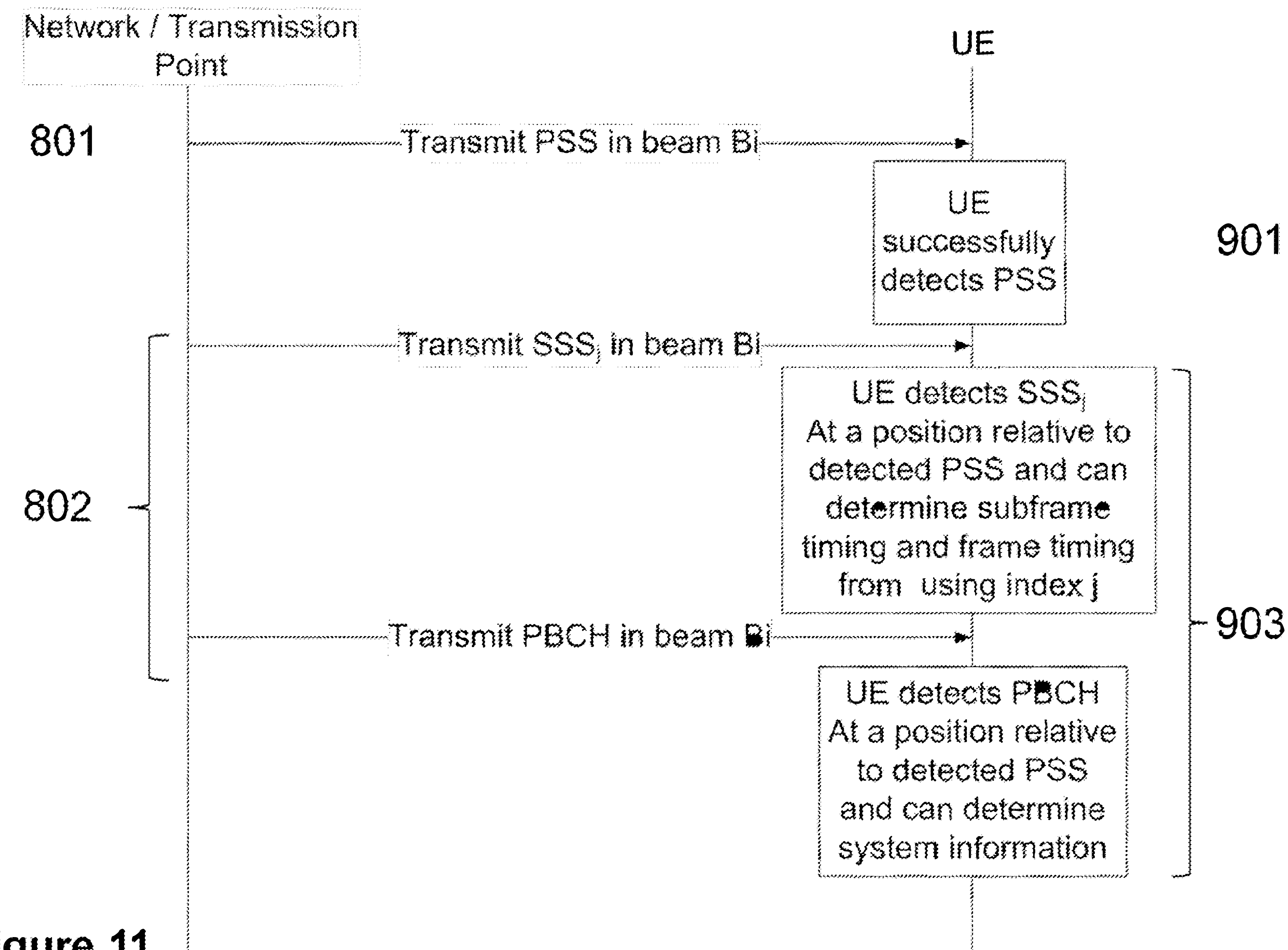
Network / Transmission Point
UE
801
Transmit PSS in beam Bi
UE successfully detects PSS
901
Transmit SSS$_j$ in beam Bi
UE detects SSS$_j$ At a position relative to detected PSS and can determine subframe timing and frame timing from using index j
802
Transmit PBCH in beam Bi
903
UE detects PBCH At a position relative to detected PSS and can determine system information

Figure 11

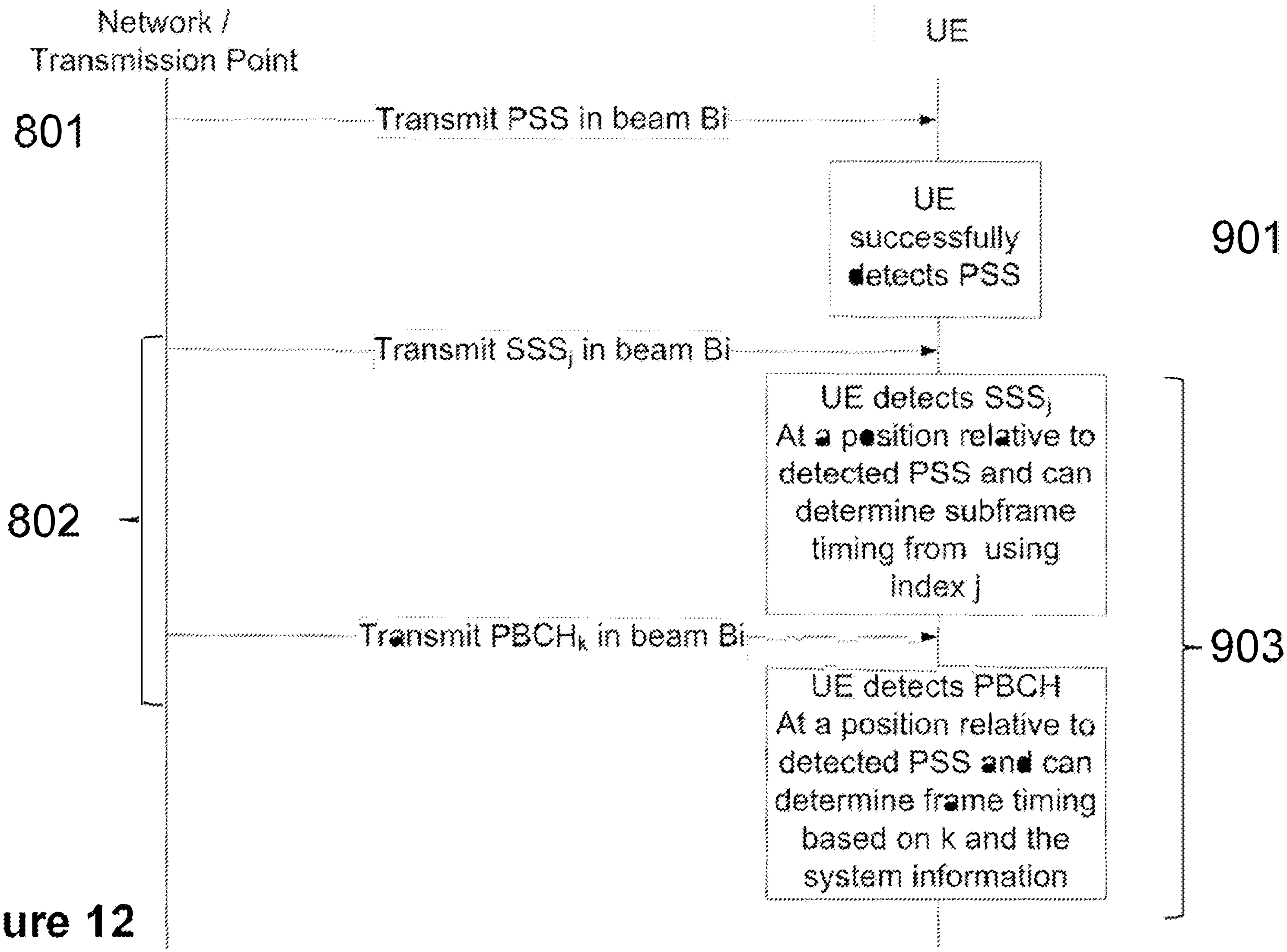
Network / Transmission Point
UE
801
Transmit PSS in beam Bi
UE successfully detects PSS
901
802
Transmit SSS_j in beam Bi
UE detects SSS_j At a position relative to detected PSS and can determine subframe timing from using index j
Transmit $PBCH_k$ in beam Bi
903
UE detects PBCH At a position relative to detected PSS and can determine frame timing based on k and the system information

Figure 12

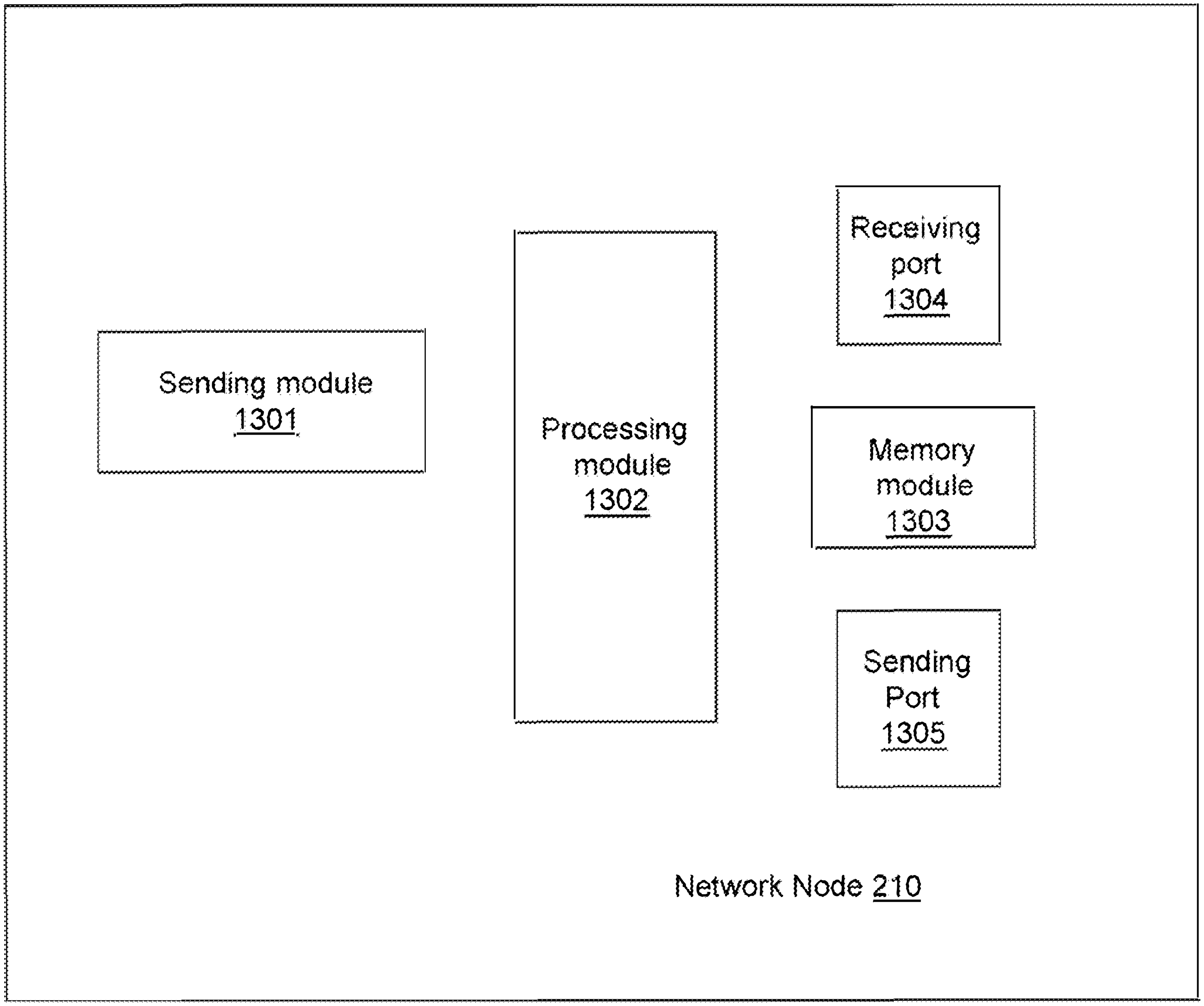
Receiving port 1304
Sending module 1301
Processing module 1302
Memory module 1303
Sending Port 1305
Network Node 210

Figure 13

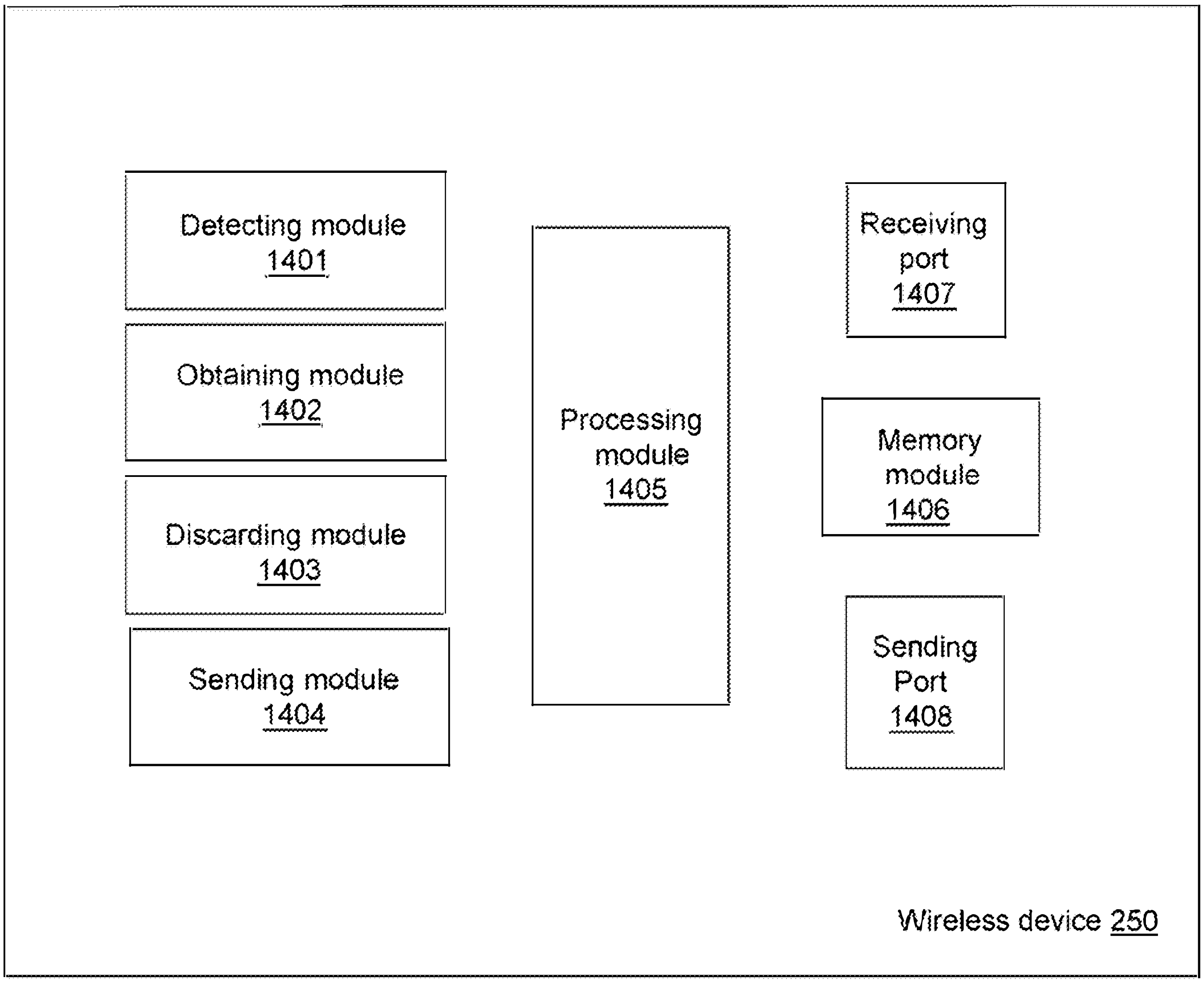
Detecting module 1401
Obtaining module 1402
Discarding module 1403
Sending module 1404
Processing module 1405
Receiving port 1407
Memory module 1406
Sending Port 1408
Wireless device 250

Figure 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2014/051144

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04J11/00
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)
H04J 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, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/307726 A1 (PI ZHOUYUE [US] ET AL) 6 December 2012 (2012-12-06)	1-6,9, 10,12, 13, 17-23, 26,27, 29,30, 34-38
A	paragraph [0002] paragraph [0004] paragraph [0023] - paragraph [0032] paragraph [0042] - paragraph [0062] paragraph [0075] - paragraph [0086] figures 4,5,6a,6b,8a,8b -----	7,8,11, 14-16, 24,25, 28,31-33

[ ] 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
14 January 2015	22/01/2015

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	Larcinese, Annamaria

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2014/051144

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

[Continued on next page]

(54) Title: INCREMENTAL TRANSMISSION OF SYSTEM INFORMATION

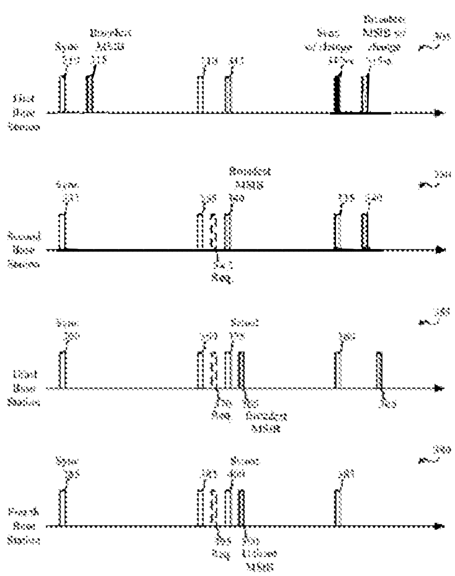

FIG. 3

(57) Abstract: Methods, systems, and devices are described for wireless communication. A first method includes receiving, at a user equipment (UE), a first set of system information; determining, based at least in part on the first set of system information, that additional system information is available; transmitting a request for the additional system information; and receiving the additional system information at the UE. A second method includes transmitting, from a base station, a first set of system information; receiving a request for additional system information; and transmitting the additional system information based at least in part on the request.

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INCREMENTAL TRANSMISSION OF SYSTEM INFORMATION

CROSS REFERENCES

[0001] The present Application for Patent claims priority to U.S. Patent Application No. 14/804,095 by Kubota et al., entitled "Incremental Transmission of System Information," filed July 20, 2015; and U.S. Provisional Patent Application No. 62/114,158 by Kubota et al., entitled "Incremental Transmission of System Information," filed February 10, 2015; each of which is assigned to the assignee hereof.

BACKGROUND

FIELD OF THE DISCLOSURE

[0002] The present disclosure, for example, relates to wireless communication systems, and more particularly to the transmission of on-demand system information in a wireless communication system, such as a wireless communication system having a user equipment (UE)-centric network.

DESCRIPTION OF RELATED ART

[0003] Wireless communication systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users by sharing the available system resources (*e.g.*, time, frequency, and power). Examples of such multiple-access systems include code-division multiple access (CDMA) systems, time-division multiple access (TDMA) systems, frequency-division multiple access (FDMA) systems, and orthogonal frequency-division multiple access (OFDMA) systems.

[0004] By way of example, a wireless multiple-access communication system may include a number of base stations, each simultaneously supporting communication for multiple communication devices, otherwise known as user equipments (UEs). A base station may communicate with UEs on downlink channels (*e.g.*, for transmissions from a base station to a UE) and uplink channels (*e.g.*, for transmissions from a UE to a base station).

[0005] In a wireless multiple-access communication system, each cell of a network may broadcast synchronization signals and system information for UEs to discover. Upon discovering the synchronization signals and system information broadcast by a particular cell, a UE may perform an initial access procedure to access the network via the cell. The cell via which the UE accesses the network may become the UE's serving cell. As the UE moves within the network, the UE may discover other cells (*e.g.*, neighboring cells) and determine whether a handover of the UE to a neighboring cell or a cell reselection is warranted.

SUMMARY

[0006] The present disclosure generally relates to wireless communication systems, and more particularly to the transmission of on-demand system information in a wireless communication system, such as a wireless communication system having a user equipment (UE)-centric medium access control (MAC) layer. Wireless communication systems such as Long Term Evolution (LTE) communication systems or LTE-Advanced (LTE-A) communication systems have a network-centric MAC layer. In a wireless communication system having a network-centric MAC layer, the network perpetually broadcasts synchronization signals and system information for UEs to discover. Upon discovering the synchronization signals and system information broadcast by a particular cell, a UE may perform an initial access procedure to access the network via the cell. Once connected to the network, the UE may discover other cells as it moves within the network. The other cells may broadcast different synchronization signals or system information. A wireless communication system having a network-centric MAC layer therefore entails various signal broadcasts, which broadcasts consume power and may or may not be received or used by some or all of a cell's UEs.

[0007] A wireless communication system having a network-centric MAC layer also places relatively more of the network processing on UEs (*e.g.*, a UE identifies a first serving cell upon initially accessing the network, and then identifies and monitors handover targets (other serving cells) as part of its mobility management). The present disclosure therefore describes a wireless communication system in which system information may be transmitted after being requested by one or more UEs. In some cases, the system information may be transmitted to a UE in a unicast or narrow-beam operation. In some cases, the wireless communication system in which the system information is transmitted may have a UE-centric MAC layer.

[0008] In a first set of illustrative examples, a method for wireless communication is described. In one configuration, the method may include receiving, at a UE, a first set of system information; determining, based at least in part on the first set of system information, that additional system information is available; transmitting a request for the additional system information; and receiving the additional system information at the UE.

[0009] In some embodiments of the method, receiving the first set of system information may include receiving an indication of one or more sets of additional system information that are available. In some embodiments of the method, transmitting the request may include identifying, in the request, one or more sets of additional system information. In some embodiments of the method, receiving the first set of system information may include receiving master system information, where the master system information includes system information that allows the UE to perform an initial access of a network using one or more of an identification of the network, an identification of a base station in the network, cell selection configuration and access restrictions, or network access configuration information. In some embodiments of the method, receiving the additional system information may include receiving system information indicating which radio access technologies (RATs) are available in a region and how the UE is to select an available RAT. In some embodiments of the method, receiving the additional system information may include receiving system information indicating which services are available in a region and how the UE is to obtain an available service. In some embodiments of the method, receiving the additional system information may include receiving system information relating to a multimedia broadcast multicast service (MBMS) or a public warning system (PWS) service. In some embodiments of the method, receiving the additional system information may include receiving system information relating to location, positioning, or navigation services.

[0010] In some embodiments of the method, receiving the first set of system information may include receiving the first set of system information in response to a master system information request. In some of these examples, the method may include sending the master system information request in accordance with information decoded from a downlink channel indicating that the master system information is received via request. The downlink channel may include a synchronization signal.

[0011] In some embodiments of the method, transmitting the request may include including one or more capabilities of the UE in the request. In some of these examples, receiving the additional system information may include receiving the additional system information based at least in part on the one or more capabilities of the UE included in the request.

[0012] In some embodiments of the method, transmitting the request may include including a location of the UE in the request. In some of these examples, receiving the additional system information may include receiving the additional system information based at least in part on the location of the UE included in the request.

[0013] In some embodiments of the method, receiving the additional system information may include receiving the additional system information based at least in part on a determined location of the UE. In some embodiments, the method may include receiving a location signal identifying a determined location of the UE, and transmitting the request for the additional system information based at least in part on the determined location of the UE. In some embodiments of the method, determining that additional system information is available may include identifying a distance between a current location of the UE and a location where the UE obtained the first set of system information, and determining that the identified distance exceeds a predetermined threshold.

[0014] In some embodiments of the method, transmitting the request may include including an identification of the UE in the request. In some of these examples, receiving the additional system information may include receiving the additional system information based at least in part on the identification of the UE included in the request. In some embodiments of the method, transmitting the request may include transmitting a plurality of requests for the additional system information.

[0015] In a second set of illustrative examples, an apparatus for wireless communication is described. In one configuration, the apparatus may include means for receiving, at a UE, a first set of system information; means for determining, based at least in part on the first set of system information, that additional system information is available; means for transmitting a request for the additional system information; and means for receiving the additional system information at the UE. In some examples, the apparatus may further include means for implementing one or more aspects of the method for wireless communication described above with respect to the first set of illustrative examples.

[0016] In a third set of illustrative examples, another apparatus for wireless communication is described. In one configuration, the apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be executable by the processor to receive, at a UE, a first set of system information; to determine, based at least in part on the first set of system information, that additional system information is available; to transmit a request for the additional system information; and to receive the additional system information at the UE. In some examples, the instructions may also be executable by the processor to implement one or more aspects of the method for wireless communication described above with respect to the first set of illustrative examples.

[0017] In a fourth set of illustrative examples, a non-transitory computer-readable medium storing computer-executable code for wireless communication is described. In one configuration, the code may be executable by a processor to receive, at a user equipment UE, a first set of system information; to determine, based at least in part on the first set of system information, that additional system information is available; to transmit a request for the additional system information; and to receive the additional system information at the UE. In some examples, the code may also be used to implement one or more aspects of the method for wireless communication described above with respect to the first set of illustrative examples.

[0018] In a fifth set of illustrative examples, another method for wireless communication is described. In one configuration, the method may include transmitting, from a base station, a first set of system information; receiving a request for additional system information; and transmitting the additional system information based at least in part on the request.

[0019] In some embodiments of the method, transmitting the first set of system information may include transmitting an indication of one or more sets of additional system information that are available. In some embodiments of the method, receiving the request may include receiving multiple requests for additional system information corresponding to multiple sets of additional system information to be transmitted. In some embodiments of the method, transmitting the first set of system information may include transmitting master system information, where the master system information includes system information that allows a UE an initial access of a network using one or more of an identification of the network, an identification of the base station, cell selection configuration and access restrictions, or network access configuration. In some embodiments of the method, transmitting the additional system information may include transmitting system information indicating which RATs are available in a region and how a UE is to select an available RAT. In some embodiments of the method, transmitting the additional system information may include transmitting system information indicating which services are available in a region and how a UE is to obtain an available service. In some embodiments of the method, transmitting the additional system information may include transmitting system information relating to location, positioning, or navigation services. In some embodiments of the method, transmitting the first set of system information may include transmitting the first set of system information in response to receiving a master system information request.

[0020] In some embodiments of the method, receiving the request may include receiving, in the request, one or more capabilities of a UE transmitting the request. In some of these examples, the method may include identifying the additional system information to transmit based at least in part on the one or more capabilities of the UE included in the request.

[0021] In some embodiments of the method, receiving the request may include receiving, in the request, a location of a UE transmitting the request. In some of these examples, the method may include identifying the additional system information to transmit based at least in part on the location of the UE included in the request. In some embodiments, the method may include determining a location of a UE transmitting the request, and identifying the additional system information to transmit based at least in part on the location of the UE. In some embodiments, the method may include receiving a location of a UE transmitting the request, and identifying the additional system information to transmit based at least in part on the location of the UE.

[0022] In some embodiments of the method, receiving the request may include receiving, in the request, an identification of a UE transmitting the request. In some of these examples, the method may include identifying the additional system information to transmit based at least in part on the identification of the UE included in the request. In some examples of the method, identifying the additional system information to transmit may include accessing a database that includes the identification of the UE transmitting the request and one or more capabilities of the UE.

[0023] In a sixth set of illustrative examples, another apparatus for wireless communication is described. In one configuration, the apparatus may include means for transmitting, from a base station, a first set of system information; means for receiving a request for additional system information; and means for transmitting the additional system information based at least in part on the request. In some examples, the apparatus may further include means for implementing one or more aspects of the method for wireless communication described above with respect to the fifth set of illustrative examples.

[0024] In a seventh set of illustrative examples, another apparatus for wireless communication is described. In one configuration, the apparatus may include a processor, memory in electronic communication with the processor, and instructions stored in the memory. The instructions may be executable by the processor to transmit, from a base station, a first set of system information; to receive a request for additional system information, and to transmit the additional system information based at least in part on the request. In some examples, the instructions may also be executable by the processor to implement one or more aspects of the method for wireless communication described above with respect to the fifth set of illustrative examples.

[0025] In an eighth set of illustrative examples, another non-transitory computer-readable medium storing computer-executable code for wireless communication is described. In one configuration, the code may be executable by a processor to transmit, from a base station, a first set of system information; to receive a request for additional system information; and to transmit the additional system information based at least in part on the request. In some examples, the code may also be used to implement one or more aspects of the method for wireless communication described above with respect to the fifth set of illustrative examples.

[0026] The foregoing has outlined rather broadly the features and technical advantages of examples according to the disclosure in order that the detailed description that follows may be better understood. Additional features and advantages will be described hereinafter. The conception and specific examples disclosed may be readily utilized as a basis for modifying