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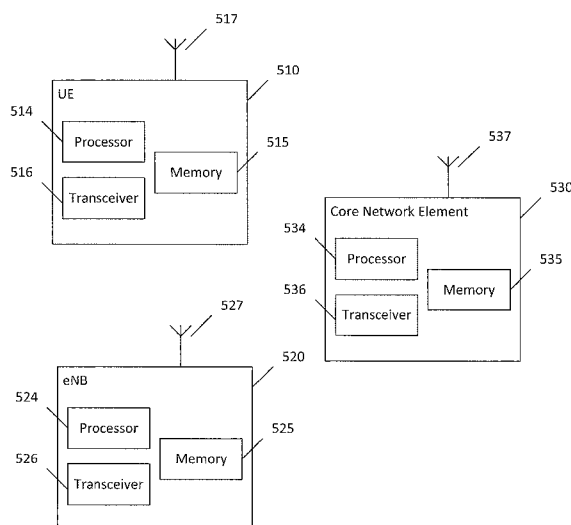


Figure 5

(57) Abstract: Various communication systems may benefit from enhancements to robustness of various indications. For example, 3GPP LTE-Advanced technology Rel-12 may benefit from enhancements of robustness of TDD UL/DL configuration indication for LTE TDD enhancement for DL-UL Interference Management and Traffic Adaptation (TDD_eIMTA). Additionally, an HARQ timing problem can also be solved according to certain embodiments.



ENHANCEMENT OF THE ROBUSTNESS OF TIME DIVISION DUPLEX UPLINK/DOWNLINK CONFIGURATION INDICATION

BACKGROUND:

5 Field:

[0001] Various communication systems may benefit from enhancements to robustness of various indications. For example, third generation partnership project (3GPP) long term evolution-advanced (LTE-Advanced) technology release 12 (Rel-12) may benefit from enhancements of robustness of a time
10 division duplex (TDD) uplink/downlink (UL/DL) configuration indication for LTE TDD enhancement for DL-UL Interference Management and Traffic Adaptation (TDD_eIMTA). Additionally, a hybrid automatic repeat request (HARQ) timing problem due to TDD UL/DL configuration changes can also be solved according to certain embodiments.

15 Description of the Related Art:

[0002] Currently, LTE TDD allows for asymmetric UL-DL allocations by providing seven different semi-statically configured TDD UL-DL configurations shown in Figure 1. These allocations can provide between 40% and 90% DL subframes. The current mechanism for adapting UL-DL allocation
20 is based on the system information change procedure with 640ms period. The concrete TDD UL/DL configuration is semi-statically informed by SIB-1 signaling.

[0003] Within further enhancements to LTE TDD for DL-UL interference management and traffic adaptation, TDD_eIMTA is a feature for LTE Rel-12 or
25 beyond, whose motivation is to realize the traffic adaptation to match the uplink and downlink traffic variation.

[0004] Various signaling solutions may be possible for indicating UL/DL configuration. One approach is implicit signaling. In this approach the concrete UL/DL configuration is not indicated so that UE just follows a reference UL/DL
30 configuration for HARQ timing.

[0005] Another approach, explicit L1 signaling of reconfiguration is used by UE-group-common enhanced physical downlink control channel ((e)PDCCH). Conventionally it is not defined what search space is used for this signaling, nor is a fallback solution defined to improve reliability and robustness of the explicit solution. Similarly, the necessary UL scheduling timing and HARQ timing signaling is not defined. This approach needs to avoid additional blind decodes.

[0006] Other alternatives, such as explicit L1 signaling by UE-specific physical downlink control channel (PDCCH) or explicit medium access control (MAC) signaling are also possible. Thus, explicit common physical layer (PHY) signaling can be used to indicate the TDD UL/DL configuration.

[0007] For common PHY signaling, a new DCI with cyclic redundancy check (CRC) scrambled by a new radio network temporary identifier (RNTI) is defined and transmitted in common search space, for example, downlink control information (DCI) format 1C. For PHY signaling, the average probability of a missed downlink scheduling grant is 1%. Moreover, eNB cannot know whether UE correctly decodes the TDD UL/DL configuration information since there is no HARQ feedback procedure for common L1 signaling. Considering the importance of correctly receiving UL/DL configuration information, the reliability and robustness may need to be further enhanced.

[0008] Moreover, a HARQ timing problem may exist. For TDD eIMTA, the Rel-8 HARQ timing is not applicable since transmission direction of some subframes is dynamically changed. One example shown in Figure 2, in case of TDD UL/DL configuration 1, if UE receives physical downlink shared channel (PDSCH) in DL subframe 9, it shall transmit corresponding A/N on physical uplink control channel (PUCCH) in UL subframe 3 in next radio frame according to currently specified LTE HARQ timing rules. If the current TDD UL/DL configuration is switched to TDD UL/DL configuration 2 to adapt to the traffic fluctuation, then subframe 3 in next radio frame will be DL subframe. Then the UE cannot feed back A/N in subframe 3 and conventionally needs to find other uplink subframe to transmit A/N. Therefore, HARQ timing according

to a reference configuration could be considered in TDD eIMTA. Thus, Figure 2 illustrates HARQ timing problem in case of dynamic TDD UL/DL reconfiguration.

[0009] From the performance point of view, it may be beneficial to support all
5 existing seven UL-DL configurations for TDD eIMTA. Therefore, UL/DL configuration 5 and 0 are used as DL and UL reference configuration, respectively. That is to say, if TDD eIMTA is enabled, the DL HARQ timing can always be based on the 1:9 UL-DL subframe configuration and UL HARQ operation can always be based on the 6:4 UL-DL subframe configuration,
10 regardless of the actual UL-DL subframe configuration in use in a frame or half a frame.

[0010] Nevertheless, employing that extremely UL-heavy or DL-heavy configuration as reference configuration also imposes constraints on performance of flexible traffic adaptation. The 9:1 configuration for DL HARQ
15 timing requires ACK/NAK feedback for 9 DL subframes in one UL subframe, causing large UL control overhead in that subframe, and may also limit the coverage range. Although ACK/NACK bundling can be configured, it may result in some DL throughput loss.

[0011] Similarly, using UL/DL configuration 0 as UL reference timing requires
20 double physical HARQ indicator channel (PHICH) resource reservation. On the other hand, the HARQ timing problem happens only in the subframe whose corresponding ACK/NACK or PUSCH are transmitted in the flexible subframes of next radio frame. Always using reference configuration may have some performance loss due to ACK/NACK bundling operation. Hence, using
25 reference configuration to solve HARQ timing problem is conventionally problematic.

[0012] Multiple repetition of TDD UL/DL configuration indication in one radio frame is one way to enhance the reliability of explicit L1 signaling. However, this requires more signaling overhead in multiple subframes in each radio frame
30 especially considering the resource limitation of common search space.

Moreover, the reliability of this UE-common DCI has not been improved due to only 16 bits CRC for error checking.

[0013] Regarding HARQ timing for TDD eIMTA, one approach is to use the fixed or semi-statically configured reference configuration, with the drawbacks discussed above. Another approach is to use dynamic reference configuration which has been specified in Rel-11 TDD inter-band CA with different UL/DL configurations on different bands to solve HARQ timing problem. However, there may be potential misalignment of TDD UL/DL configuration between eNB and UE when the reconfiguration signaling is not received correctly (i.e. in case of false alarm or miss). Another issue for this method is the higher implementation complexity to dynamically adjust HARQ timing on a frame basis. Therefore, the dynamically adjusted HARQ timing based on the latest configuration may not be appropriate for TDD UL/DL reconfiguration with time scale of 10 ms.

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SUMMARY:

[0014] According to certain embodiments, a method can include preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The method can also include transmitting the user equipment-common downlink control information in the fixed downlink subframe.

[0015] In certain embodiments, a method can include receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The method can also include validating the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary

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identifier.

[0016] An apparatus, according to certain embodiments, can include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code can be configured to, with the
5 at least one processor, cause the apparatus at least to prepare a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The at least one memory and the computer program code
10 can also be configured to, with the at least one processor, cause the apparatus at least to transmit the user equipment-common downlink control information in the fixed downlink subframe.

[0017] An apparatus, in certain embodiments, can include at least one processor and at least one memory including computer program code. The at least one
15 memory and the computer program code can be configured to, with the at least one processor, cause the apparatus at least to receive a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in
20 the next frame. The at least one memory and the computer program code can also be configured to, with the at least one processor, cause the apparatus at least to validate the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary identifier.

[0018] According to certain embodiments, an apparatus can include means for preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed
25 downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The apparatus can also include means for transmitting the user equipment-common downlink
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control information in the fixed downlink subframe.

[0019] In certain embodiments, an apparatus can include means for receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The apparatus can also include means for validating the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary identifier.

[0020] A method, according to certain embodiments, can include configuring a time scale of time division duplex uplink/downlink configuration repetition in high layer signaling. The method can also include repeating the time division duplex uplink/downlink configuration according to the high layer signaling.

[0021] An apparatus, in certain embodiments, can include at least one processor and at least one memory including computer program code. The at least one memory and the computer program code can be configured to, with the at least one processor, cause the apparatus at least to configure a time scale of time division duplex uplink/downlink configuration repetition in high layer signaling. The at least one memory and the computer program code can also be configured to, with the at least one processor, cause the apparatus at least to repeat the time division duplex uplink/downlink configuration according to the high layer signaling.

[0022] According to certain embodiments, an apparatus can include means for configuring a time scale of time division duplex uplink/downlink configuration repetition in high layer signaling. The apparatus can also include means for repeating the time division duplex uplink/downlink configuration according to the high layer signaling.

[0023] In certain embodiments, a non-transitory computer-readable medium can be encoded with instructions that, when executed in hardware perform a process.

The process can include preparing a user equipment-common downlink control

information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The process can also include transmitting the user equipment-common downlink control information in the fixed downlink subframe.

[0024] A non-transitory computer-readable medium can, according to certain embodiments, be encoded with instructions that, when executed in hardware perform a process. The process can include receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The process can also include validating the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary identifier.

[0025] A non-transitory computer-readable medium can, in certain embodiments, be encoded with instructions that, when executed in hardware perform a process. The process can include configuring a time scale of time division duplex uplink/downlink configuration repetition in high layer signaling. The process can also include repeating the time division duplex uplink/downlink configuration according to the high layer signaling.

[0026] According to certain embodiments, a computer program product can encode instructions for performing a process. The process can include preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The process can also include transmitting the user equipment-common downlink control information in the fixed downlink subframe.

[0027] In certain embodiments, a computer program product can encode

instructions for performing a process. The process can include receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The process can also include validating the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary identifier.

[0028] A computer program product can, according to certain embodiments, encode instructions for performing a process. The process can include configuring a time scale of time division duplex uplink/downlink configuration repetition in high layer signaling. The process can also include repeating the time division duplex uplink/downlink configuration according to the high layer signaling.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0029] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

[0030] Figure 1 illustrates current seven kinds of a time division duplex uplink/downlink configurations.

[0031] Figure 2 illustrates a hybrid automatic repeat request timing problem in case of dynamic time division duplex uplink/downlink reconfiguration.

[0032] Figure 3 illustrates a method according to certain embodiments.

[0033] Figure 4 illustrates another method according to certain embodiments.

[0034] Figure 5 illustrates a system according to certain embodiments.

DETAILED DESCRIPTION:

[0035] Certain embodiments focus on enhancing the robustness and reliability of UL/DL configuration transmitted in common search space for TDD eIMTA.

Additionally, certain embodiments address optimization for HARQ-ACK

feedback for DL and UL transmission. Moreover, at least one HARQ timing problem can be solved using certain embodiments.

[0036] In certain embodiments, UE-common DCI for indicating TDD UL/DL configuration can be transmitted in one fixed downlink subframe which is used to indicate the TDD UL/DL configuration to be used in the next frame.

[0037] In certain embodiments, a life cycle indication (LCI) can be contained in the UE-common DCI for indicating TDD UL/DL configuration. The LCI can be used to indicate the number of the following consecutive frames the indicated UL/DL configuration is to be used in, and this value can be updated by minus 1 in each following frame, for example, the value can be decremented each frame.

[0038] The same TDD UL/DL configuration indication can be repeated in the following consecutive frames indicated by LCI value. So the DL HARQ timing, UL HARQ timing and PUSCH timing can follow the practical UL/DL configuration due to no UL/DL configuration being changed in the following consecutive frames.

[0039] When LCI value minus 1 is equal to 0, it can be updated in next frame according to the UL and DL traffic amount and/or ratio with the limitation of no larger than the maximum value represented by LCI.

[0040] More particularly, when an LCI value is set to 1, it can mean the indicated UL/DL configuration will be used in the following frame and a different UL/DL configuration may be used in the frame after the next. Then the predefined or semi-statically configured DL/UL reference configuration can be used to guarantee that the HARQ timing can work properly if the UL/DL configuration in the frame after the next is really changed to another different one compared with its previous frame. Otherwise, the DL HARQ timing, UL HARQ timing and PUSCH timing can still follow the practical UL/DL configuration due to no UL/DL configuration changed in the consecutive frames. The eNB can detect UL ACK/NACK or PUSCH according to the predefined or semi-statically configured DL/UL reference configuration in case that the TDD UL/DL configuration is changed. Alternatively, the eNB can try to detect UL

ACK/NACK or PUSCH according to the predefined or semi-statically configured DL/UL reference configuration after it does not detect that according to the practical TDD UL/DL configuration in case the TDD UL/DL configuration is not changed.

5 [0041] Upon receiving this common DCI, the UE can first validate it with a 16-bit CRC scrambled by the predefined RNTI. Then the UE can validate whether the LCI value received in this frame is equal to that in previous frame minus 1, if the LCI value in previous frame is larger than 1. Thus, the UE can detect the indicated TDD UL/DL configuration with very high reliability.

10 [0042] For error case handling, if UE misses the common DCI in current frame and the current frame is included in the life cycle of previous TDD UL/DL configuration (for example, when the LCI value in the previous frame is larger than 1), then UE can use the same UL/DL configuration as that in previous frame. If the UE misses the common DCI in current frame and the current frame
15 is not included in the life cycle of previous TDD UL/DL configuration (for example, LCI value in previous frame is equal to 1), then the UE can use the predefined or semi-statically configured DL/UL reference configuration in order to guarantee the HARQ timing works properly.

[0043] In order to further enhance the reliability, in the UE-common DCI for
20 indicating TDD UL/DL configuration, one bit can be contained for even or odd checking aligned with whether a current system frame number (SFN) is even or odd.

[0044] Alternatively, the time scale can be configured and signaled by high layer. So the TDD UL/DL configuration can be indicated in the first frame and always
25 repeated in the following frames within one reconfiguration period. In this way, HARQ timing can always follow the practical TDD UL/DL configuration within same reconfiguration period. During the boundary from one reconfiguration period to the next, the UE can follow the predefined or semi-statically configured DL/UL reference configuration in order to guarantee
30 the HARQ timing works properly.

[0045] In certain embodiments, the approach can improve the reliability and robustness of TDD UL/DL configuration indication for TDD eIMTA. Meanwhile, HARQ timing problem can be optimized.

[0046] Currently, several UL-DL interference mitigation schemes are possible, including, for example, Cell Clustering Interference Mitigation (CCIM), downlink power reduction or uplink power boosting in conflicting subframes. For CCIM, coordination among neighboring cells may be needed to determine the most appropriate TDD UL/DL configuration for all the small cells within one cluster according to the traffic fluctuation in UL and DL for the whole cluster. Considering the non-ideal backhaul between two small cells or Macro cell and small cell, for example, several tens of ms delay, TDD eIMTA cannot dynamically change the TDD UL/DL configuration every 10ms. In that sense, the selected UL/DL configuration may be used in the several following consecutive frames. Assuming the backhaul delay is 40ms, at least once a UL/DL configuration is selected, it may need to be kept unchanged in the following four frames. It is also true for DL power reduction and UL power boosting in conflicting subframes due to the backhaul delay when TDD UL/DL configurations of neighboring cells are exchanged.

[0047] Furthermore, although physical layer signaling can support the time scale of 10ms for UL/DL reconfiguration, 10ms as a time scale does not necessarily mean the used TDD UL/DL configuration will be switched to another different one every 10ms. First, reconfiguration every 10ms may lead to high complexity for implementation. Second, TDD eIMTA may mainly be adopted in small cells like Pico or Femto with dynamic or bursty traffic in downlink or uplink. Especially in case of large data file downloading or uploading, the UL/DL traffic ratio may be kept unchanged or may remain similar, and thus may not necessarily be changed to another one. Third, even with a fast reconfiguration rate of 10ms, the period of system staying in one UL/DL configuration may be much longer than a frame period. Fourth, a 40ms time scale may have quite a similar performance to a 10ms time scale.

Thus, one TDD UL/DL configuration can be kept unchanged for several following frames.

[0048] Based on this, a life cycle indication (LCI) can be contained in the UE-common DCI for indicating TDD UL/DL configuration. LCI can be used to indicate the number of the following consecutive frames the indicated UL/DL configuration to be used in and can be updated by minus 1 in each following frame. The LCI value can dependent on the number of bits for LCI indication. For example, assuming two bits are used for LCI indication, the maximum value and minimum value of LCI may be 4 and 1, respectively. If one TDD UL/DL configuration will be used for the following four frames, then two-bit LCI shall be indicated to “11” in current frame and “10” in next frame, and so on till “00” in the fourth frame. A detailed mapping relationship between LCI bit and LCI value is shown in Table 1.

[0049] When LCI value minus 1 is equal to 0, for example, two-bit LCI in DCI is (0, 0), it shall be updated in next frame according to the UL and DL traffic amount and ratio with the limitation of no larger than the maximum value represented by LCI.

Table 1: mapping relationship between LCI bit and LCI value

LCI bit (MSB, LSB)	LCI value
(1, 1)	4
(1, 0)	3
(0, 1)	2
(0, 0)	1

[0050] The above table is one example mapping. Other mappings are possible, such as one in which (0, 0) corresponds to 4, (0, 1) corresponds to 3, and so forth.

[0051] The same TDD UL/DL configuration indication can be repeated in the following consecutive frames indicated by LCI value.

[0052] Regarding the HARQ timing, the DL HARQ timing, UL HARQ timing and PUSCH timing can follow the practical UL/DL configuration due

to no UL/DL configuration changed in the following consecutive frames. When the UL/DL configuration is changed to another different one, the predefined or semi-statically configured DL/UL reference configuration can be used to guarantee the HARQ timing works properly.

5 [0053] When LCI is set to 1 it can mean that the indicated UL/DL configuration will be used in the following frame and a different UL/DL configuration may be used in the frame after the next. If the UL/DL configuration in the frame after the next is really changed to another different one compared with its previous frame then, at the UE side, the UE can follow
10 the predefined or semi-statically configured DL/UL reference configuration. At the eNB side, the eNB can detect UL ACK/NACK or PUSCH according to the predefined or semi-statically configured DL/UL reference configuration. [0054] If the UL/DL configuration in the frame after the next is not changed then, at the UE side, the UE can follow the practical UL/DL configuration. At
15 the eNB side, the eNB can try to detect UL ACK/NACK or PUSCH according to the predefined or semi-statically configured DL/UL reference configuration after it does not detect that according to the practical TDD UL/DL configuration.

[0055] Upon receiving this common DCI indicating TDD UL/DL
20 configuration, UE shall first validate it with 16-bit CRC scrambled by the predefined RNTI then validate whether the LCI received in this frame is equal to that in previous frame minus 1 if the LCI value in the previous frame is larger than 1. Then the UE can detect the indicated TDD UL/DL configuration with very high reliability.

25 [0056] For error case handling, if UE misses the common DCI in current frame and the current frame is included in the life cycle of the previous TDD UL/DL configuration, for example, LCI value in previous frame is larger than 1, then UE can use the same UL/DL configuration as that in previous frame. Alternatively, if the UE misses the common DCI in the current frame and the
30 current frame is not included in the life cycle of the previous TDD UL/DL

configuration, for example, LCI value in previous frame is equal to 1, then UE can use the predefined or semi-statically configured DL/UL reference configuration in order to guarantee the HARQ timing works properly.

[0057] It is noted that the number of LCI indications can also be 1, 3, or other values which are also included in certain embodiments. Although the details of such embodiments are not explicitly provided, they may be inferred from the embodiment in which the LCI indications are 4.

[0058] In order to further enhance the reliability, in the UE-common DCI for indicating TDD UL/DL configuration, one bit can be contained for even or odd checking aligned with whether a current system frame number (SFN) is even or odd. For example, if $(\text{SFN} \bmod 2 == 0)$ then this bit can be set to 0; otherwise, this bit can be set to 1. Upon receiving this DCI, the UE can validate this bit field with a current SFN number. In this way, error-checking capability can be further enhanced.

[0059] In this way, HARQ timing can always follow the practical TDD UL/DL configuration within same reconfiguration period. During the boundary from one reconfiguration period to the next, the UE can follow the predefined or semi-statically configured DL/UL reference configuration in order to guarantee the HARQ timing works properly. In that sense, DL or UL performance loss can be further avoided due to ACK/NACK bundling.

[0060] Regarding the subframe for transmitting TDD UL/DL configuration in common search space, in certain embodiments this UE-common DCI is transmitted in one fixed downlink subframe, for example, in the second half-frame. So the indicated TDD UL/DL configuration is to be used in next frame. A benefit of transmitting UE-common DCI in downlink subframe 5 or 6 is it can only solve the HARQ timing problems for boundary subframes, whose corresponding A/N or scheduled PUSCH can be transmitted in the following frame. Moreover, UE has enough time to buffer the data if the number of HARQ processes is changed in next frame.

[0061] Although additional signaling bits are used, certain embodiments may

have various benefits and advantages. For example, certain embodiments may further enhance the robustness and reliability of UE-common DCI for TDD UL/DL configuration indication. Moreover, certain embodiments may solve a HARQ timing problem by indicating TDD reconfiguration set.

5 Furthermore, certain embodiments may avoid necessary UE power consumption for blind detection.

[0062] Figure 3 illustrates a method according to certain embodiments. As shown in Figure 3, a method can include, at 310, preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe of, for example, a second half-frame that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame. The method can also include, at 320, transmitting the user equipment-common downlink control information in the fixed downlink subframe.

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[0063] The preparing can involve, at 312, including, in the user equipment-common downlink control information, a life cycle indication. The life cycle indication can be configured to indicate a number of following consecutive frames in which the indicated time division duplex uplink/downlink configuration is to be used.

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[0064] At 314, the preparing can also involve including, in the user equipment-common downlink control information, one bit for even or odd checking aligned with whether a current system frame number is even or odd.

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[0065] The method can also include, at 330, decrementing the life cycle indication in each following frame until the life cycle indication reaches a predetermined minimum value.

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[0066] The method can further include, at 340, repeating a time division duplex uplink/downlink configuration indication in the following consecutive frames indicated by the life cycle indication value.

[0067] The method can further include, at 350, updating the life cycle indication in a next frame after the life cycle indication value is one, wherein the updating

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is based on uplink and downlink traffic amount and/or ratio with a limitation of no larger than a maximum value represented by the life cycle indication.

[0068] The method of Figure 3 may be performed by, for example, a base station such as an evolved Node B. Other devices are permitted to perform the method.

5 [0069] Figure 4 illustrates another method according to certain embodiments. As shown in Figure 4, a method can include, at 410, receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration in one fixed downlink subframe of, for example, the second half-frame which is used to indicate the time division
10 duplex uplink/downlink configuration to be used in the next frame. The method can also include, at 420, validating the user equipment-common downlink control information with a 16-bit cyclic redundancy check scrambled by a predefined radio network temporary identifier.

[0070] The method can further include, at 440, validating whether a life cycle
15 indication value received in this frame is equal to that in previous frame minus the number of frames in between the latest received life cycle indication value and the current frame if the life cycle indication value in the previous frame is larger than one. For example, if the UE receives in one frame a LCI with a certain count, and misses the next one, it can still compare the latest received
20 LCI with the one received two frames ago. In other words, the verification is not limited to a UE that received an LCI in two consecutive frames.

[0071] At 450, the method can include, when the user equipment misses the user equipment-common downlink control information in a current frame and the current frame is included in the life cycle of a previous time division duplex
25 uplink/downlink configuration, using a same time division duplex uplink/downlink configuration as that in a previous frame. Likewise, the method can include, at 460, when the user equipment misses the user equipment-common downlink control information in the current frame and the current frame is not included in the life cycle of the previous time division
30 duplex uplink/downlink configuration, using a predefined or semi-statically

configured time division duplex uplink/downlink configuration as uplink/downlink reference configuration.

[0072] Figure 5 illustrates a system according to certain embodiments of the invention. In one embodiment, a system may include multiple devices, such as, for example, at least one UE 510, at least one eNB 520 or other base station or access point, and at least one core network element 530. In certain systems, only UE 510 and eNB 520 may be present, and in other systems UE 510, eNB 520, and a plurality of other user equipment may be present. Other configurations are also possible.

[0073] Each of these devices may include at least one processor, respectively indicated as 514, 524, and 534. At least one memory can be provided in each device, and indicated as 515, 525, and 535, respectively. The memory may include computer program instructions or computer code contained therein. The processors 514, 524, and 534 and memories 515, 525, and 535, or a subset thereof, can be configured to provide means corresponding to the various blocks of each of Figures 3 and 4.

[0074] As shown in Figure 5, transceivers 516, 526, and 536 can be provided, and each device may also include at least one antenna, respectively illustrated as 517, 527, and 537. Other configurations of these devices, for example, may be provided. For example, core network element 530 may be configured for wired communication, rather than wireless communication, and in such a case antenna 537 would illustrate any form of communication hardware, without requiring a conventional antenna.

[0075] Transceivers 516, 526, and 536 can each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that is configured both for transmission and reception.

[0076] Processors 514, 524, and 534 can be embodied by any computational or data processing device, such as a central processing unit (CPU), application specific integrated circuit (ASIC), or comparable device. The processors can be implemented as a single controller, or a plurality of controllers or processors.

[0077] Memories 515, 525, and 535 can independently be any suitable storage device, such as a non-transitory computer-readable medium. A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory can be used. The memories can be combined on a single integrated circuit as the processor, or may be separate from the one or more processors. Furthermore, the computer program instructions stored in the memory and which may be processed by the processors can be any suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language.

[0078] The memory and the computer program instructions can be configured, with the processor for the particular device, to cause a hardware apparatus such as UE 510, eNB 520, and core network element 530, to perform any of the processes described above (see, for example, Figures 3 and 4). Therefore, in certain embodiments, a non-transitory computer-readable medium can be encoded with computer instructions that, when executed in hardware, perform a process such as one of the processes described herein. Alternatively, certain embodiments of the invention can be performed entirely in hardware.

[0079] Furthermore, although Figure 5 illustrates a system including a UE, eNB, and core network element, embodiments of the invention may be applicable to other configurations, and configurations involving additional elements. For example, not shown, additional UEs may be present.

[0080] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. In order to determine the metes and bounds of the invention, therefore, reference should be made to the appended claims.

- [0081] Partial Glossary
- [0082] LTE Long term evolution
- [0083] DL Downlink
- [0084] eNB evolved Node B
- 5 [0085] DAI Downlink assignment index
- [0086] DCI Downlink control information
- [0087] TPC Transmit power control
- [0088] GP Guard period
- [0089] RRC Radio resource control
- 10 [0090] UE User equipment
- [0091] UL Uplink

WHAT IS CLAIMED IS:

1. A method, comprising:

preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed
5 downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and

transmitting the user equipment-common downlink control information in the fixed downlink subframe.

10 2. The method of claim 1, wherein the preparing comprises including, in the user equipment-common downlink control information, a life cycle indication.

3. The method of claim 2, wherein the life cycle indication is configured
15 to indicate a number of following consecutive frames in which the indicated time division duplex uplink/downlink configuration is to be used.

4. The method of claim 2, further comprising:
decrementing the life cycle indication in each following frame until the
20 life cycle indication reaches a predetermined minimum value.

5. The method of claim 2, further comprising:
repeating a time division duplex uplink/downlink configuration
indication in the following consecutive frames indicated by the life cycle
25 indication value.

6. The method of claim 2, further comprising:
updating the life cycle indication in a next frame after the life cycle
indication value reaches a predefined minimum value, wherein the updating is
30 based on uplink and downlink traffic amount and/or ratio with a limitation of no

larger than a maximum value represented by the life cycle indication.

7. The method of claim 1, wherein the preparing comprises including, in the user equipment-common downlink control information, one bit for even or
5 odd checking aligned with whether a current system frame number is even or odd.

8. A method, comprising:
receiving a user equipment-common downlink control information for
10 indicating time division duplex uplink/downlink configuration in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and
validating the user equipment-common downlink control information with a cyclic redundancy check scrambled by a predefined radio network
15 temporary identifier.

9. The method of claim 8, further comprising:
receiving a life cycle indication in the user equipment-common downlink control information; and
20 validating whether the life cycle indication value received in this frame is equal to that in a previous frame minus the number of frames in between the latest received life cycle indication value and the current frame if the life cycle indication value in the previous frame is larger than a predefined minimum value.

10. The method of claim 8, further comprising:
when the user equipment misses the user equipment-common downlink control information in a current frame and the current frame is included in the life cycle of a previous time division duplex uplink/downlink configuration
25 indication, using a same time division duplex uplink/downlink configuration as
30

that in a previous frame; and

when the user equipment misses the user equipment-common downlink control information in the current frame and the current frame is not included in the life cycle of the previous time division duplex uplink/downlink configuration indication, using a predefined or semi-statically configured time
5 division duplex uplink/downlink reference configuration.

11. An apparatus, comprising:

at least one processor; and

10 at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to prepare a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed
15 downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and

transmit the user equipment-common downlink control information in the fixed downlink subframe.

20 12. The apparatus of claim 11, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to include, in the user equipment-common downlink control information, a life cycle indication.

25 13. The apparatus of claim 12, wherein the life cycle indication is configured to indicate a number of following consecutive frames in which the indicated time division duplex uplink/downlink configuration is to be used.

14. The apparatus of claim 12, wherein the at least one memory and the
30 computer program code are configured to, with the at least one processor, cause

the apparatus at least to decrement the life cycle indication in each following frame until the life cycle indication reaches a predetermined minimum value.

15 15. The apparatus of claim 12, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to repeat a time division duplex uplink/downlink configuration indication in the following consecutive frames indicated by the life cycle indication value.

10 16. The apparatus of claim 12, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to update the life cycle indication in a next frame after the life cycle indication value is equal to a predefined minimum value, wherein the updating is based on uplink and downlink traffic amount and/or ratio with a
15 limitation of no larger than a maximum value represented by the life cycle indication.

17. The apparatus of claim 11, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause
20 the apparatus at least to include, in the user equipment-common downlink control information, one bit for even or odd checking aligned with whether a current system frame number is even or odd.

18. An apparatus, comprising:
25 at least one processor; and
 at least one memory including computer program code,
 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to
 receive a user equipment-common downlink control information for
30 indicating time division duplex uplink/downlink configuration in one fixed

downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and

validate the user equipment-common downlink control information with a cyclic redundancy check scrambled by a predefined radio network temporary identifier.

19. The apparatus of claim 18, further comprising:

receive a life cycle indication in the user equipment-common downlink control information; and

validate whether the life cycle indication value received in this frame is equal to that in previous frame minus the number of frames in between the latest received life cycle indication value and the current frame if the life cycle indication value in the previous frame is larger than a predefined minimum value.

20. The apparatus of claim 18, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:

when the user equipment misses the user equipment-common downlink control information in a current frame and the current frame is included in the life cycle of a previous time division duplex uplink/downlink configuration, use a same time division duplex uplink/downlink configuration as that in a previous frame; and

when the user equipment misses the user equipment-common downlink control information in the current frame and the current frame is not included in the life cycle of the previous time division duplex uplink/downlink configuration, using a predefined or semi-statically configured time division duplex uplink/downlink reference configuration.

21. An apparatus, comprising:

means for preparing a user equipment-common downlink control information for indicating a time division duplex uplink/downlink configuration in one fixed downlink subframe that is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and

5 means for transmitting the user equipment-common downlink control information in the fixed downlink subframe.

22. The apparatus of claim 21, wherein the means for preparing comprises means for including, in the user equipment-common downlink control information, a life cycle indication.

23. The apparatus of claim 22, wherein the life cycle indication is configured to indicate a number of following consecutive frames in which the indicated time division duplex uplink/downlink configuration is to be used.

15

24. The apparatus of claim 22, further comprising:

means for decrementing the life cycle indication in each following frame until the life cycle indication reaches a predetermined minimum value.

20 25. The apparatus of claim 22, further comprising:

means for repeating a time division duplex uplink/downlink configuration indication in the following consecutive frames indicated by the life cycle indication value.

25 26. The apparatus of claim 22, further comprising:

means for updating the life cycle indication in a next frame after the life cycle indication value is equal to a predefined minimum value, wherein the updating is based on uplink and downlink traffic amount and/or ratio with a limitation of no larger than a maximum value represented by the life cycle indication.

30

27. The apparatus of claim 21, wherein the means for preparing comprises means for including, in the user equipment-common downlink control information, one bit for even or odd checking aligned with whether a
5 current system frame number is even or odd.

28. An apparatus, comprising:

means for receiving a user equipment-common downlink control information for indicating time division duplex uplink/downlink configuration
10 in one fixed downlink subframe which is used to indicate the time division duplex uplink/downlink configuration to be used in the next frame; and

means for validating the user equipment-common downlink control information with a cyclic redundancy check scrambled by a predefined radio network temporary identifier.
15

29. The apparatus of claim 28, further comprising:

means for receiving a life cycle indication in the user equipment-common downlink control information; and

means for validating whether the life cycle indication value received in
20 this frame is equal to that in previous frame minus the number of frames in between the latest received life cycle indication value and the current frame if the life cycle indication value in the previous frame is larger than a predefined minimum value.

25 30. The apparatus of claim 28, further comprising:

means for, when the user equipment misses the user equipment-common downlink control information in a current frame and the current frame is included in the life cycle of a previous time division duplex uplink/downlink configuration, using a same time division duplex uplink/downlink configuration
30 as that in a previous frame; and

means for, when the user equipment misses the user equipment-common downlink control information in the current frame and the current frame is not included in the life cycle of the previous time division duplex uplink/downlink configuration, using a predefined or semi-statically configured time division duplex uplink/downlink reference configuration.

31. A non-transitory computer-readable medium encoded with instructions that, when executed in hardware perform a process, the process comprising the method according to any of claims 1-10.

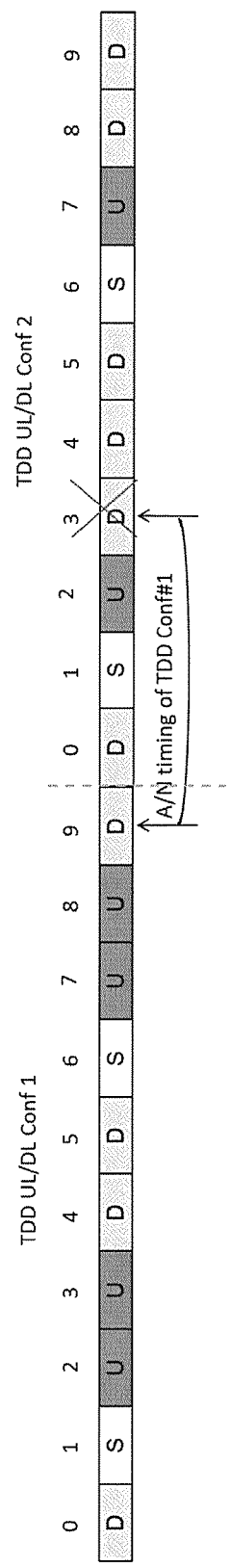
10

32. A computer program product encoding instructions for performing a process, the process comprising the method according to any of claims 1-10.

UL/DL configuration	Switching-point periodicity	Subframe number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

Related Art

Figure 1



Related Art

Figure 2

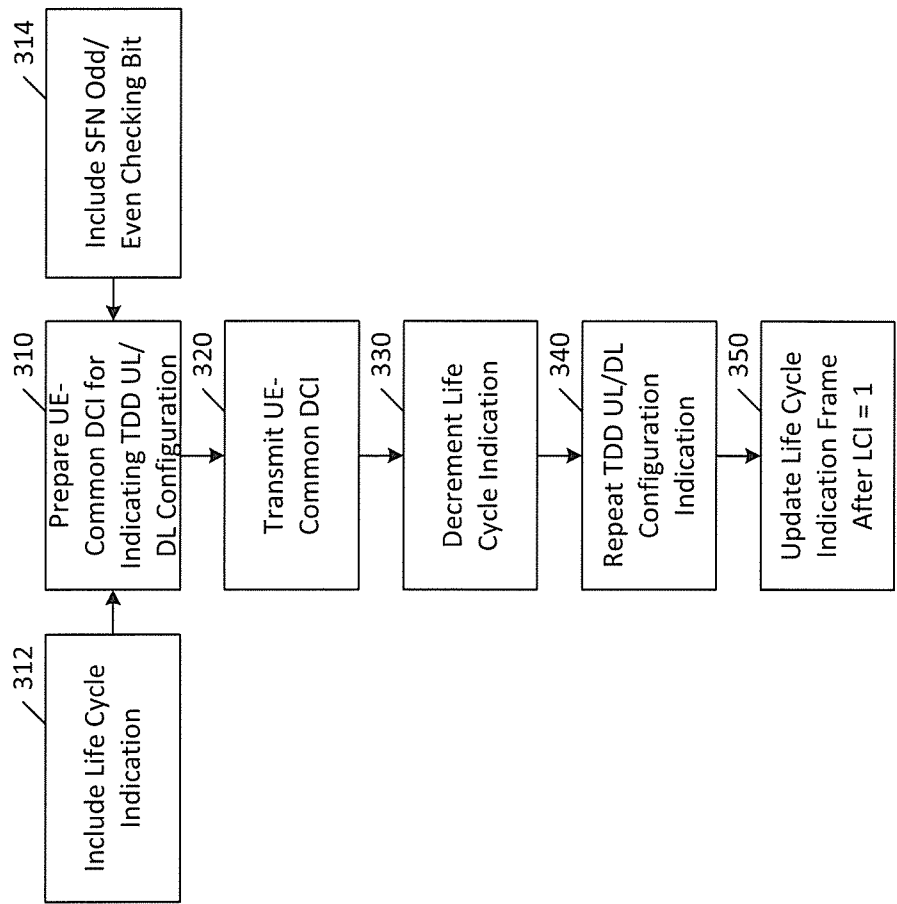


Figure 3

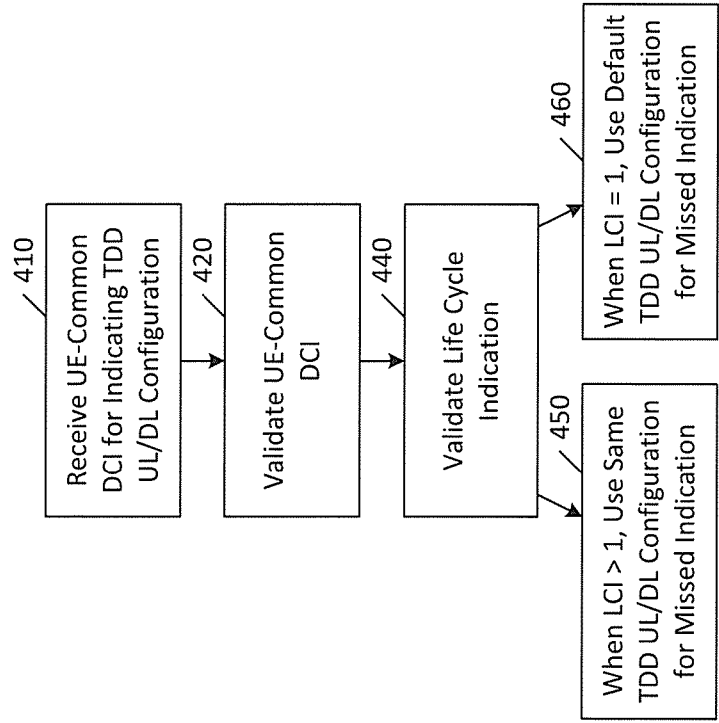


Figure 4

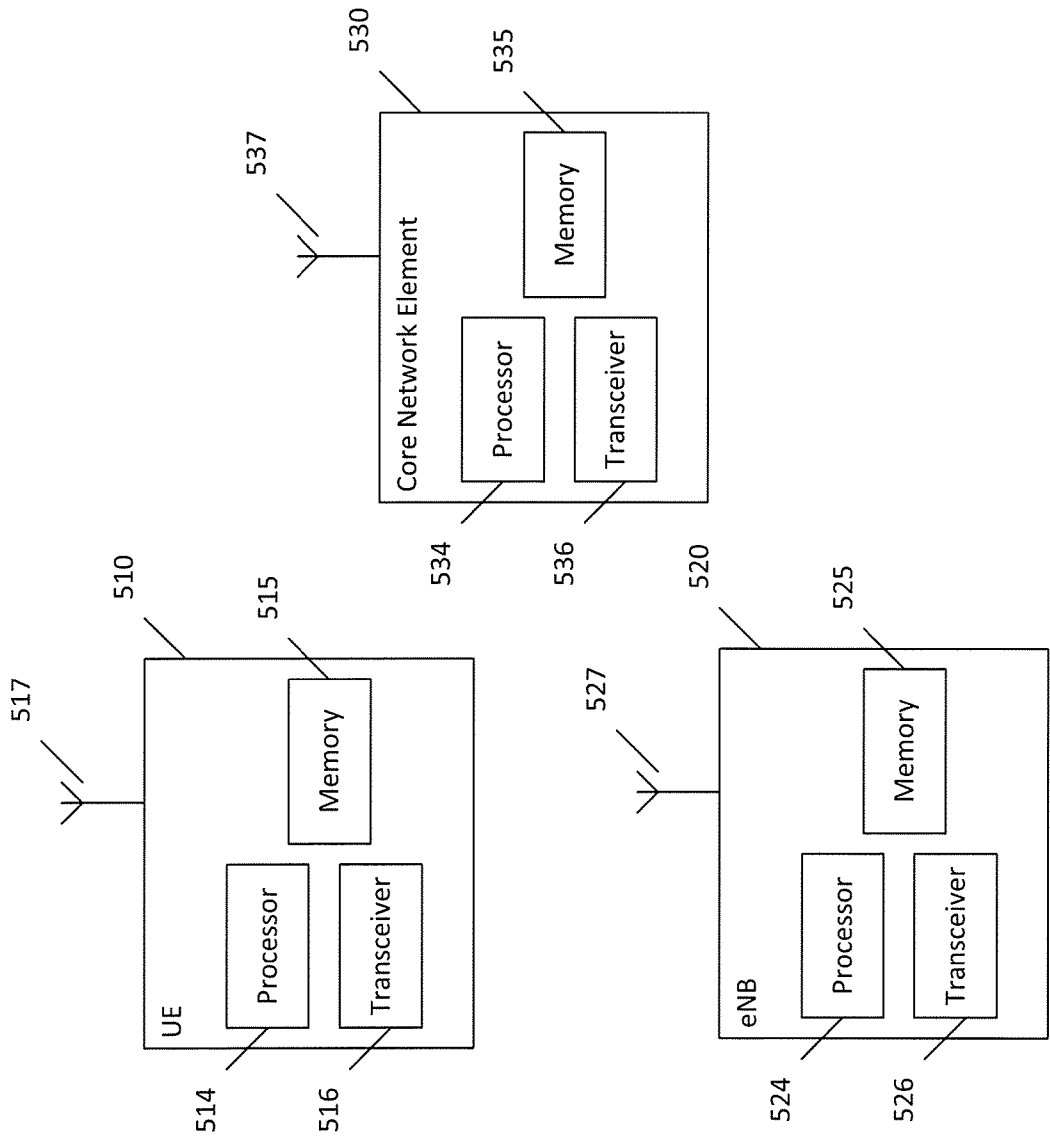


Figure 5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/080994

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W, H04L, H04B

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)

WPI,EPODOC,CNPAT,CNKI,3GPP: TDD, time division duplex, downlink, DL, uplink, UL, configuration, reconfiguration, indicate, fixed, subframe, life cycle, validity, period, miss, check.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RENESAS MOBILE EUROPE LTD., . "Further Discussion on Signaling Schemes for TDD eIMTA", "3GPP TSG RAN WG1 Meeting #73, RI-132168, , 24 May 2013 (2013-05-24), sections 1, 2.3, 3 and 4	1, 7-8, 11, 17-18, 21, 27-28, 31-32
Y	RENESAS MOBILE EUROPE LTD., . "Further Discussion on Signaling Schemes for TDD eIMTA", "3GPP TSG RAN WG1 Meeting #73, RI-132168, , 24 May 2013 (2013-05-24), sections 1, 2.3, 3 and 4	2-6, 9-10, 12-16, 19-20, 22-26, 29-30
Y	WO 2012113131A1 (RENESAS MOBILE CORP.) 30 August 2012 (2012-08-30) description, page 10, line 5 to page 20, line 2	2-6, 9-10, 12-16, 19-20, 22-26, 29-30
A	WO 2012155323A1 (RENESAS MOBILE CORP.) 22 November 2012 (2012-11-22) the whole document	1-32

☐ Further documents are listed in the continuation of Box C.☒ 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	"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
"E"	earlier application or patent but published on or after the international filing date	"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
"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)	"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
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

22 April 2014

Date of mailing of the international search report

19 May 2014

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN2013/080994

Patent document cited in search report		Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO	2012113131A1	30 August 2012	EP 2679068A1	01 January 2014
			CN 103493556A	01 January 2014
			US 2013336177A1	19 December 2013
WO	2012155323A1	22 November 2012	CN 103518413A	15 January 2014
			DE 112011105244T5	20 February 2014
			EP 2707985A1	19 March 2014
			US 2014098720A1	10 April 2014