

(51) International Patent Classification:
H04W 40/00 (2009.01)(21) International Application Number:
PCT/CN2013/070704(22) International Filing Date:
18 January 2013 (18.01.2013)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **BROAD-COM CORPORATION** [US/US]; 5300 California Avenue, Irvine, California 92617 (US).

(72) Inventors; and

(71) Applicants (for US only): **HAN, Jing** [CN/CN]; Room 1606, Building 3, Xi Ba He Xi Li Residential Area, Chaoyang District, Beijing 100028 (CN). **WANG, Haiming** [CN/CN]; Room 1403, Unit 5, Building 101, Jiang Fu Jia Yuan, Jiang Tai Road, Chaoyang District, Beijing 100015(CN). **GAO, Chunyan** [CN/CN]; Room 271, Building 6, Ru Yi Li, Bei Cao Chang Hu Tong, Xi Zhi Men Nei Da Jie, Xicheng District, Beijing 100035 (CN). **ZHANG, Lili** [CN/CN]; Room #1704, Building B of Chang Kun Ming Ju, Ban Bi Jie South Road, Num 2, Haidian District, Beijing 100089 (CN). **HONG, Wei** [CN/CN]; Room 606, Haidian North Second Street, Haidian District, Beijing 100080 (CN).(74) Agent: **KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Center, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU,

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR SUPPORTING TIME DIVISION DUPLEX UPLINK/DOWNLINK RECONFIGURATION

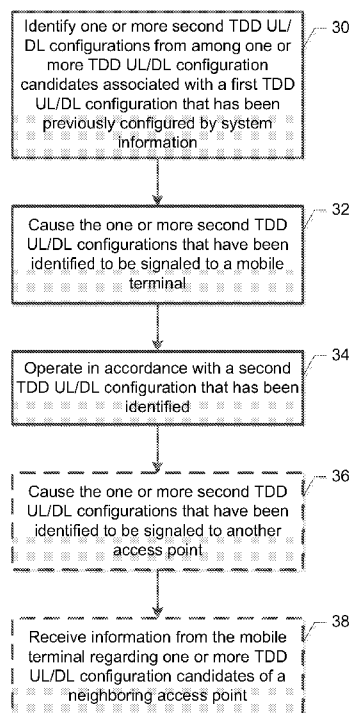


FIG. 3

(57) Abstract: A method, apparatus and computer program product are provided to support TDD UL/DL reconfiguration, such as to adapt to traffic within a respective cell. The method, apparatus and computer program product may identify the TDD UL/DL configuration to be utilized by a cell in a manner that reduces signaling overhead and error case handling, such as by implicit PHY signaling. The method, apparatus and compute program may identify a reference configuration for the HARQ timeline, either via explicit or implicit signaling, so as to reduce the loss because of a HARQ timeline change in conjunction with a TDD UL/DL reconfiguration.



RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ,
TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA,
ZM, ZW.

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, ML, MR, NE, SN, TD, TG).

(84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

METHOD AND APPARATUS FOR SUPPORTING TIME DIVISION DUPLEX UPLINK/DOWNLINK RECONFIGURATION

TECHNOLOGICAL FIELD

- 5 [0001] An example embodiment of the present invention relates generally to wireless communications and, more generally, to time division duplex uplink/downlink reconfiguration.

BACKGROUND

- 10 [0002] A time division duplex (TDD) system permits asymmetric uplink (UL)/downlink (DL) allocation. For example, the asymmetric resource allocation in a long term evolution (LTE) TDD system is supported by seven different semi-statically configured UL/DL configurations. These configurations provide between 40% and 90% DL subframes.
- 15 [0003] In an LTE system, the same TDD configuration is generally assumed for each cell since interference between the UL and the DL, including both base station-to-base station and mobile terminal-to-mobile terminal interference would otherwise need to be considered. In this regard, a base station may provide system information, such as via system information block 1 (SIB1), to identify the TDD UL/DL configuration to the
- 20 mobile terminals operating within a cell. However, in some networks, such as in a local area (LA) network, the traffic supported by a cell may fluctuate frequently, such as due to a relatively small number of active mobile terminals per cell. In order to improve resource efficiency, provide power savings and reduce traffic delays, the TDD UL/DL configuration may be reconfigured to adapt to the traffic.
- 25 [0004] In regard to TDD UL/DL reconfiguration, several different time scales for such reconfiguration have been considered in relation to the various deployment scenarios. For example, in an instance in which multiple pico cells are under the coverage of a macro cell, a fast TDD UL/DL reconfiguration that will result in a fast

interference change and fast inter-base station coordination may not be available.

However, signaling of the TDD UL/DL reconfiguration within the physical (PHY) layer supports TDD UL/DL reconfiguration with a time scale of adaptation on the order of ten milliseconds (ms). In conjunction with PHY signaling, the TDD UL/DL configuration or the transmission direction of a subframe can be explicitly indicated by the physical channel or signal or the transmission direction of a subframe can be implicitly derived by the mobile terminal based upon the base station scheduling and configurations for uplink transmissions.

[0005] In regard to TDD UL/DL reconfiguration, the resulting system should also maintain backwards compatibility with legacy TDD mobile terminals. In order to continue to support legacy TDD mobile terminals, a subframe that is a downlink subframe in the initial TDD UL/DL configuration, as may be defined, for example, by SIB1, cannot be changed to an uplink subframe by the TDD UL/DL reconfiguration since a legacy TDD mobile terminal would not appreciate the reconfiguration and would otherwise monitor the frame originally indicated to be a DL subframe, such as for common reference signals (CRS) including, for example, radio resource management (RRM) measurements and periodic channel state information (CSI) reporting. However, for a number of initial TDD UL/DL configurations, there may be additional TDD UL/DL configurations that have the same DL subframes as the initial TDD UL/DL configuration. Thus, these additional TDD UL/DL configurations could also support legacy TDD mobile terminals. By way of example, the additional TDD UL/DL configurations associated with each of the initial TDD UL/DL configurations are shown below in Table 1, along with the resulting TDD UL/DL configuration set formed by the combination of the initial TDD UL/DL configuration and the additional TDD UL/DL configurations.

Table 1

Initial TDD UL/DL Configuration	Additional TDD UL/DL Configurations Having Same DL Subframes	TDD Configuration Set
0	1, 2, 6	[0, 1, 2, 6]
1	2	[1, 2]

2	Not applicable	[2]
3	4, 5	[3, 4, 5]
4	5	[4, 5]
5	Not applicable	[5]
6	1, 2	[6, 1, 2]

Another example of the additional TDD UL/DL configurations associated with each of the initial TDD UL/DL configurations are shown below in Table 2, along with the resulting TDD UL/DL configuration set formed by the combination of the initial TDD

5 UL/DL configuration and the additional TDD UL/DL configurations.

Table 2

Initial TDD UL/DL Configuration	Additional TDD UL/DL Configurations	TDD Configuration Set
0	1, 2, 3, 4, 5, 6	[0, 1, 2, 3, 4, 5, 6]
1	2, 3, 4, 5	[1, 2, 3, 4, 5]
2	3, 4, 5	[2, 3, 4, 5]
3	4, 5	[3, 4, 5]
4	5	[4, 5]
5	Not applicable	[5]
6	1, 2, 3, 4, 5	[1, 2, 3, 4, 5, 6]

[0006] In the foregoing example, the various TDD UL/DL configurations are referenced in terms of the seven predefined TDD UL/DL configurations for an LTE TDD system. With reference to Table 2, for example, if the SIB1 indicates that the initial TDD UL/DL configuration is TDD UL/DL configuration 0, the base station may reconfigure the TDD UL/DL configuration to be TDD UL/DL configurations 1, 2 or 6 in subsequent subframes for mobile terminals that support flexible TDD UL/DL configurations, while the legacy mobile terminals that do not support flexible TDD UL/DL configurations will continue to operate in accordance with TDD UL/DL configuration 0. In this example, each of TDD UL/DL configurations 0, 1, 2 and 6 have the same DL subframes so that the legacy mobile terminals can operate effectively, even in an instance in which the TDD UL/DL configuration changes with the TDD configuration set.

[0007] Many operations involving the base station and the mobile terminal depend upon a TDD UL/DL configuration including, for example, RRM measurements, channel quality indicator (CQI) measurements, channel estimation, physical downlink control

channel (PDCCH) detection and hybrid automatic repeat request (HARQ) timing. In order to provide for TDD UL/DL reconfiguration, such as to adapt to traffic within a respective cell, a base station may signal the TDD UL/DL reconfiguration via, for example, the radio resource control (RRC), media access control (MAC) or PHY layers.

- 5 The PHY layer signaling provides the smallest time scale for reconfiguration and provides the largest gain.

[0008] The PHY layer signaling can be provided either explicitly or implicitly with implicit PHY signaling generally being more flexible and requiring less signaling overheard. While straightforward, explicit signaling increases signaling overhead and
10 may create additional error case handling. In contrast, implicit signaling permits a mobile terminal to determine the TDD UL/DL configuration based upon, for example, the scheduling grant. However, the link direction of a subframe may only be determined by a mobile terminal after grant detection. Thus, prior to grant detection, a mobile terminal must assume that each frame (other than subframe 2 which is fixed as an UL subframe) is
15 a DL subframe and detect PDCCH in the respective subframe unless a UL grant has been detected for the respective subframe, thereby potentially consuming additional power. Additionally, in an instance in which a mobile terminal is not scheduled in one subframe such that no grant is detected, a mobile terminal will be unable to determine whether the respective subframe is a DL subframe or a UL subframe, such that the mobile terminal
20 may be unable to utilize the respective subframe for measurement purposes.

[0009] The foregoing issues are exacerbated in instances in which there are more possible TDD UL/DL configurations since there will be additional uncertainty in regard to the link direction of the subframes. For example, if SIB1 indicates that the cell will initially operate in accordance with TDD UL/DL configuration 0, the mobile terminal
25 may determine that subframes 3, 4, 8 and 9 can be either DL subframes or UL subframes since the additional TDD UL/DL configurations to which the cell may be reconfigured from TDD UL/DL configuration 0 may include TDD UL/DL configurations 1, 2 and 6,

as shown in Table 1 above. As such, the mobile terminal of this example may allow for PDCCH detection in all of subframes 0, 1, 3, 4, 5, 6, 8 and 9 since subframes 0, 1, 5 and 6 are indicated to be DL subframes for TDD UL/DL configuration 0 and subframes 3, 4, 8 and 9 may be defined as DL subframe by TDD UL/DL configurations 1, 2 and 6 unless
5 an uplink grant has been detected for one or more of the subframes. By performing PDCCH detection for each of these subframes, the mobile terminal may expend an undesirable amount of power. Additionally, these same subframes generally cannot be utilized for DL measurement if no DL grant was detected in the respective subframe since a mobile terminal is unsure as to whether the respective subframe is a UL or DL
10 subframe.

[0010] The HARQ timeline is dependent upon a TDD UL/DL configuration. However, in instances in which the TDD UL/DL reconfiguration changes relatively frequently, such as on a 10 ms time scale, the HARQ timeline is also changed frequently, which may result in larger loss by HARQ. In this regard, in an instance in which the
15 HARQ timeline is changed, there may be feedback or (re-)transmission loss for the subframe that includes the feedback or uplink grant, in the changed TDD UL/DL configuration. Thus, in an instance in which the HARQ timeline is changed frequently, such as in an instance in which the TDD UL/DL configuration is changed frequently, loss attributable to the HARQ timeline change may be significant.

20 [0011] It has been proposed in R1-120782 that in an instance in which the TDD UL/DL configuration is changed based on a 10 ms, the HARQ timeline may be fixed with all feedback and grants located in a fixed subframe, such as DL subframe 0, 1, 5 and 6 and UL subframes 2 and 7. In other words, the HARQ timeline of this proposal would be such that its DL subframes track the timing of TDD UL/DL configuration 2 and its UL
25 subframes track the timing of TDD UL/DL configuration 0. However, this proposal may undesirably limit the TDD UL/DL reconfiguration since a requirement that the DL subframes always track TDD UL/DL configuration 2 results in an inability to reconfigure

the TDD UL/DL configuration to be TDD UL/DL configurations 3, 4 or 5 since subframe 7 of TDD UL/DL configurations 3, 4 and 5 is a DL subframe. Additionally, inclusion of all feedback and grants in fixed subframes may result in control overload for the fixed subframes. Furthermore, in an instance in which the uplink feedback is limited to only a fixed uplink subframe, there may be additional bundling loss which may decrease the downlink throughput.

BRIEF SUMMARY

[0012] A method, apparatus and computer program product are provided in accordance with an example embodiment of the present invention in order to support TDD UL/DL reconfiguration, such as to adapt to traffic within a respective cell. In one embodiment, a method, apparatus and computer program product are provided in order to identify the TDD UL/DL configuration to be utilized by a cell in a manner that reduces signaling overhead and error case handling, such as by implicit PHY signaling. In another embodiment, a method, apparatus and computer program are provided to identify a reference configuration for the HARQ timeline, either via explicit or implicit signaling, so as to reduce the loss because of a HARQ timeline change in conjunction with a TDD UL/DL reconfiguration.

[0013] In one embodiment, a method is provided that includes identifying one or more second time division duplex (TDD) uplink (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration candidates associated with a first TDD UL/DL configuration that has been previously configured by system information. The method of this embodiment also causes the one or more second TDD UL/DL configurations that have been identified to be signaled to a mobile terminal. Thereafter, the method of this embodiment operates in accordance with a second TDD UL/DL configuration that has been identified.

[0014] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to identify one or more second time division duplex (TDD) uplink (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration candidates associated with a first TDD UL/DL configuration that has been previously configured by system information. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus of this embodiment to cause the one or more second TDD UL/DL configurations that have been identified to be signaled to a mobile terminal and to thereafter operate in accordance with a second TDD UL/DL configuration that has been identified.

[0015] In a further embodiment, a computer program product is provided that includes at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein with the computer-executable program code portions including program code instructions for identifying one or more second time division duplex (TDD) uplink (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration candidates associated with a first TDD UL/DL configuration that has been previously configured by system information. The computer-executable program code portions of this embodiment also include program code instructions for causing the one or more second TDD UL/DL configurations that have been identified to be signaled to a mobile terminal and for operating in accordance with a second TDD UL/DL configuration that has been identified.

[0016] In yet another embodiment, an apparatus is provided that includes means for identifying one or more second time division duplex (TDD) uplink (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration candidates associated with a first TDD UL/DL configuration that has been previously configured by system information. The apparatus of this embodiment also includes means for causing the one

or more second TDD UL/DL configurations that have been identified to be signaled to a mobile terminal. Further, the apparatus of this embodiment includes means for thereafter operating in accordance with a second TDD UL/DL configuration that has been identified.

[0017] In one embodiment, a method is provided that includes determining a first
5 time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information. The method of this embodiment also includes receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information. Thereafter, the method includes identifying one of the one or
10 more second TDD UL/DL configurations and operating in accordance with the second TDD UL/DL configuration that has been identified.

[0018] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code configured to, with the at least one processor,
15 cause the apparatus at least to determine a first time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus of this embodiment to receive an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration
20 candidates associated with the first TDD UL/DL configuration that is based upon system information, identify one of the one or more second TDD UL/DL configurations and to thereafter operate in accordance with the second TDD UL/DL configuration that has been identified.

[0019] In a further embodiment, a computer program product is provided that
25 includes at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein with the computer-executable program code portions including program code instructions for determining a first time division

duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information. The computer-executable program code portions of this embodiment also include program code instructions for receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information, for identifying one of the one or more second TDD UL/DL configurations and for thereafter operating in accordance with the second TDD UL/DL configuration that has been identified.

[0020] In yet another embodiment, an apparatus is provided that includes means for determining a first time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information. The apparatus of this embodiment also includes means for receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information. The apparatus may further include means for identifying one of the one or more second TDD UL/DL configurations and means for operating in accordance with a second TDD UL/DL configuration that has been identified.

[0021] In one embodiment, a method is provided that includes causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled. The method of this embodiment also includes causing an effective period for the reference configuration to be signaled.

[0022] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to cause a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled. The at least one memory and the computer program code are also configured to,

with the at least one processor, cause the apparatus of this embodiment to cause an effective period for the reference configuration to be signaled.

[0023] In a further embodiment, a computer program product is provided that includes at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein with the computer-executable program code portions including program code instructions for causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled. The computer-executable program code portions of this embodiment also include program code instructions for causing an effective period for the reference configuration to be signaled.

[0024] In yet another embodiment, an apparatus is provided that includes means for causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled. The apparatus of this embodiment also includes means for causing an effective period for the reference configuration to be signaled.

[0025] In one embodiment, a method is provided that includes receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline. The method of this embodiment also includes receiving an indication of an effective period for the reference configuration and operating in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.

[0026] In another embodiment, an apparatus is provided that includes at least one processor and at least one memory including computer program code with the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to receive an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline. The at least one memory and the computer program

code are also configured to, with the at least one processor, cause the apparatus of this embodiment to receive an indication of an effective period for the reference configuration and operate in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.

- 5 [0027] In a further embodiment, a computer program product is provided that includes at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein with the computer-executable program code portions including program code instructions for receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request
- 10 (HARQ) timeline or a downlink (DL) HARQ timeline. The computer-executable program code portions of this embodiment also include program code instructions for receiving an indication of an effective period for the reference configuration and program code instructions for operating in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.
- 15 [0028] In yet another embodiment, an apparatus is provided that includes means for receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline. The apparatus of this embodiment also includes means for receiving an indication of an effective period for the reference configuration and means for operating in accordance
- 20 with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

- [0029] Having thus described certain embodiments of the invention in general
- 25 terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

[0030] Figure 1 is a schematic representation of a system including access point and one or more mobile terminals that may be specifically configured in accordance with an example embodiment of the present invention;

[0031] Figure 2 is a block diagram of an apparatus that may be embodied by an
5 access or a mobile terminal and that may be specifically configured in accordance with an example embodiment of the present invention;

[0032] Figure 3 is a flow chart illustrating operations performed, such as by the apparatus of Figure 2 embodied as an access point, in accordance with an example embodiment to the present invention;

10 [0033] Figure 4 illustrates an initial TDD UL/DL configuration, a second TDD UL/DL configuration and a resulting TDD UL/DL configuration following reconfiguration including the flexible subframes in accordance with an example embodiment of the present invention;

[0034] Figure 5 illustrates an initial TDD UL/DL configuration, a second TDD
15 UL/DL configuration and a resulting TDD UL/DL configuration following reconfiguration including the flexible subframes in accordance with another example embodiment of the present invention;

[0035] Figure 6 is a flow chart illustrating operations performed, such as by the apparatus of Figure 2 embodied as a mobile terminal, in accordance with an example
20 embodiment of the present invention;

[0036] Figure 7 is a flow chart illustrating the operations performed, such as by the apparatus of Figure 2 embodied as an access point, in regard to the definition of a reference configuration for the HARQ timeline in accordance with an example embodiment of the present invention; and

25 [0037] Figure 8 is a flow chart illustrating the operations performed, such as by the apparatus of Figure 2 embodied as a mobile terminal, in regard to the definition of a

reference configuration for the HARQ timeline in accordance with an example embodiment of the present invention.

DETAILED DESCRIPTION

5 [0038] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the inventions are shown. Indeed, these inventions may 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 satisfy applicable legal

10 requirements. Like numbers refer to like elements throughout.

[0039] As used in this application, the term “circuitry” refers to all of the following: (a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and (b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of
15 processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and (c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

20 [0040] This definition of “circuitry” applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term “circuitry” would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term “circuitry” would also cover, for example and if applicable to the
25 particular claim element, a baseband integrated circuit or application specific integrated circuit for a mobile phone or a similar integrated circuit in server, a cellular network device, or other network device.

[0041] A method, apparatus and computer program product are provided in accordance with an example embodiment of the present invention in order to support TDD UL/DL reconfiguration. For example, the TDD UL/DL reconfiguration supported by embodiments of the present invention may permit the TDD UL/DL configuration to adapt to traffic within a respective cell. In one embodiment, a method, apparatus and computer program product are provided in order to identify the TDD UL/DL configuration to be utilized by a cell in a manner that reduces signaling overhead and error case handling, such as by implicit PHY signaling. By defining the TDD UL/DL configuration to be utilized in this manner, the method, apparatus and computer program product of this embodiment may provide power savings and measurement accuracy and may facilitate intercell interference coordination in conjunction with dynamic reconfiguration. In another embodiment, a method, apparatus and computer program are provided to identify a reference configuration for the HARQ timeline, either via explicit or implicit signaling, so as to reduce the loss because of a HARQ timeline change in conjunction with a TDD UL/DL reconfiguration.

[0042] Referring now to Figure 1, a system that supports communications between a plurality of mobile terminals 10 (one of which is illustrated by way of example) and a network 14, such as an 802.11 network, a Long Term Evolution (LTE) network, an LTE-Advanced (LTE-A) network, a Global Systems for Mobile communications (GSM) network, a Code Division Multiple Access (CDMA) network, e.g., a Wideband CDMA (WCDMA) network, a CDMA2000 network or the like, a General Packet Radio Service (GPRS) network or other type of network, via an access point 12 is shown. The network may be a non-uniform network, such as a non-uniform universal mobile telecommunications systems (UMTS) terrestrial radio access network (UTRAN) LTE network that may include one or more macro, pico and/or femto cells. Various types of mobile terminals may be employed including, for example, mobile communication devices or user equipment such as, for example, mobile telephones, smartphones,

personal digital assistants (PDAs), pagers, laptop computers, tablet computers or any of numerous other hand held or portable communication devices, computation devices, content generation devices, content consumption devices, or combinations thereof.

Regardless of the type of mobile terminal, the mobile terminal may communicate with the network via an access point, such as a base station, a Node B, an evolved Node B (eNB), a relay node or other type of access point.

[0043] The mobile terminal 10 and a network entity, such as the access point 12, may each embody or otherwise be associated with an apparatus 20 that is generally depicted in Figure 2 and that may be configured to perform various operations in accordance with an example embodiment of the present invention as described below, such as in conjunction with Figures 6 and 8 from the perspective of the mobile terminal and Figures 3 and 7 from the perspective of a network entity, such as the access point. However, it should be noted that the components, devices or elements described below may not be mandatory and thus some may be omitted in certain embodiments. Additionally, some embodiments may include further or different components, devices or elements beyond those shown and described herein.

[0044] As shown in Figure 2, the apparatus 20 may include or otherwise be in communication with a processing system including, for example, processing circuitry 22 that is configurable to perform actions in accordance with example embodiments described herein. The processing circuitry may be configured to perform data processing, application execution and/or other processing and management services according to an example embodiment of the present invention. In some embodiments, the apparatus or the processing circuitry may be embodied as a chip or chip set. In other words, the apparatus or the processing circuitry may comprise one or more physical packages (e.g., chips) including materials, components and/or wires on a structural assembly (e.g., a baseboard). The structural assembly may provide physical strength, conservation of size, and/or limitation of electrical interaction for component circuitry included thereon. The

apparatus or the processing circuitry may therefore, in some cases, be configured to implement an embodiment of the present invention on a single chip or as a single “system on a chip.” As such, in some cases, a chip or chipset may constitute means for performing one or more operations for providing the functionalities described herein.

5 [0045] In an example embodiment, the processing circuitry 22 may include a processor 24 and memory 26 that may be in communication with or otherwise control a communication interface 28 and, in some cases in which the apparatus is embodied by the mobile terminal 10, a user interface 30. As such, the processing circuitry may be embodied as a circuit chip (e.g., an integrated circuit chip) configured (e.g., with
10 hardware, software or a combination of hardware and software) to perform operations described herein. However, in some embodiments, the processing circuitry may be embodied as a portion of mobile terminal or the access point.

[0046] The user interface 30 (if implemented in embodiments of the apparatus 20 embodied by the mobile terminal 10) may be in communication with the processing
15 circuitry 22 to receive an indication of a user input at the user interface and/or to provide an audible, visual, mechanical or other output to the user. As such, the user interface may include, for example, a keyboard, a mouse, a joystick, a display, a touch screen, a microphone, a speaker, and/or other input/output mechanisms. In one embodiment, the user interface includes user interface circuitry configured to facilitate at least some
20 functions of the station by receiving user input and providing output.

[0047] The communication interface 28 may include one or more interface mechanisms for enabling communication with other devices and/or networks. In some cases, the communication interface may be any means such as a device or circuitry embodied in either hardware, or a combination of hardware and software that is
25 configured to receive and/or transmit data from/to a network 14 and/or any other device or module in communication with the processing circuitry 22, such as between the mobile terminal 10 and the access point 12. In this regard, the communication interface may

include, for example, an antenna (or multiple antennas) and supporting hardware and/or software for enabling communications with a wireless communication network and/or a communication modem or other hardware/software for supporting communication via cable, digital subscriber line (DSL), universal serial bus (USB), Ethernet or other
5 methods.

[0048] In an example embodiment, the memory 26 may include one or more non-transitory memory devices such as, for example, volatile and/or non-volatile memory that may be either fixed or removable. The memory may be configured to store information, data, applications, instructions or the like for enabling the apparatus 20 to carry out
10 various functions in accordance with example embodiments of the present invention. For example, the memory could be configured to buffer input data for processing by the processor 24. Additionally or alternatively, the memory could be configured to store instructions for execution by the processor. As yet another alternative, the memory may include one of a plurality of databases that may store a variety of files, contents or data
15 sets. Among the contents of the memory, applications may be stored for execution by the processor in order to carry out the functionality associated with each respective application. In some cases, the memory may be in communication with the processor via a bus for passing information among components of the apparatus.

[0049] The processor 24 may be embodied in a number of different ways. For
20 example, the processor may be embodied as various processing means such as one or more of a microprocessor or other processing element, a coprocessor, a controller or various other computing or processing devices including integrated circuits such as, for example, an ASIC (application specific integrated circuit), an FPGA (field programmable gate array), or the like. In an example embodiment, the processor may be configured to
25 execute instructions stored in the memory 26 or otherwise accessible to the processor. As such, whether configured by hardware or by a combination of hardware and software, the processor may represent an entity (e.g., physically embodied in circuitry – in the form of

processing circuitry) capable of performing operations according to embodiments of the present invention while configured accordingly. Thus, for example, when the processor is embodied as an ASIC, FPGA or the like, the processor may be specifically configured hardware for conducting the operations described herein. Alternatively, as another
5 example, when the processor is embodied as an executor of software instructions, the instructions may specifically configure the processor to perform the operations described herein.

[0050] An access point 12 and a mobile terminal 10 may initially be configured to communicate in accordance with a first Time Division Duplex (TDD) uplink (UL) /
10 downlink (DL) configuration that defines the link direction of the various subframes such that the subframes are identified as being either an UL subframe or a DL subframe. The first TDD UL/DL configuration may be established based upon system information that is transmitted from the access point to the mobile terminal that identifies the first TDD UL/DL configuration. Although the system information may be provided in a variety of
15 different manners, the system information that defines the first TDD UL/DL configuration may be provided by the system information block 1 (SIB 1). Although the first TDD UL/DL configuration may be defined in various manners, the first TDD UL/DL configuration may be defined by the system information to be one of a plurality of predefined TDD UL/DL configurations, such as TDD UL/DL configuration 0, TDD
20 UL/DL configuration 1, ... TDD UL/DL configuration 7. Each of the predefined TDD UL/DL configurations has one or more TDD UL/DL configuration candidates that share the same, e.g., have common, DL subframes to facilitate backwards compatibility, as indicated above in Table 1.

[0051] Referring now to Figure 3, the operations performed by a method, apparatus
25 and computer program product of an example embodiment are illustrated from the perspective of an apparatus 20 that may be embodied by or otherwise associated with an access point 12. As shown in block 30, the apparatus may include means, such as the

processing circuitry 22, the processor 24 or the like, for identifying one or more second TDD UL/DL configurations from among the one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration. By way of example, in an instance in which the first TDD UL/DL configuration is TDD UL/DL configuration 0, the TDD UL/DL configuration candidates are TDD UL/DL configurations 1, 2 and 6. In this embodiment, the apparatus, such as the processor, may identify, for example, TDD UL/DL configuration 1 or TDD UL/DL configurations 1 and 2 or TDD UL/DL configurations 1, 2 and 6 as the second TDD UL/DL configuration from among the TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration.

[0052] The apparatus 20 may also include means, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for causing the one or more second TDD UL/DL configurations that have been identified to be signaled to a mobile terminal 10. See block 32 of Figure 3. The one or more second TDD UL/DL configurations may be signaled to the mobile terminal in various manners including with higher layer signaling, that is, signaling higher than physical layer signaling, such as RRC, MAC CE or system information, e.g., master information block (MIB) or SIB, signaling. The apparatus of this embodiment may also include means, such as the processing circuitry, the processor or the like, for selecting and thereafter operating in accordance with one of the second TDD UL/DL configuration(s) that has been identified. See block 34.

[0053] By way of example with reference to Figure 4, the first TDD UL/DL configuration 40 may be TDD UL/DL configuration 0. As indicated in Table 1 above, the TDD UL/DL configuration candidates associated with TDD UL/DL configuration 0 are TDD UL/DL configurations 1, 2 and 6. In this example, the apparatus 20 embodied by the access point 12, such as the processor 24, may identify TDD UL/DL configuration 1 to be the second TDD UL/DL configuration 42 from among the TDD UL/DL configuration candidate and may then cause the mobile terminal 10 to be signaled that

TDD UL/DL configuration 1 is the second TDD UL/DL configuration. As shown in Figure 4, TDD UL/DL configuration 1 differs from TDD UL/DL configuration 0 in that subframes 4 and 9 are UL subframes in TDD UL/DL configuration 0, but are DL subframes in TDD UL/DL configuration 1. Thus, the resulting TDD UL/DL

5 configuration 44 depicts subframes 4 and 9 as flexible subframes in that they had different link directions in the first and second TDD UL/DL configurations, but will be treated as DL subframes going forward as defined by the second TDD UL/DL configuration. In this example embodiment, the mobile terminal may recognize that subframes 3 and 8 are UL subframes, both in the first TDD UL/DL configuration and in
10 the second TDD UL/DL configuration. Thus, the mobile terminal need not attempt to detect the PDCCH in subframes 3 and 8 so as to conserve power, but may, instead, send a report, such as a CQI report, in subframes 3 or 8 regardless of whether an UL grant for subframes 3 or 8 is detected.

[0054] As another example depicted in Figure 5, the first TDD UL/DL configuration
15 40 that is configured by SIB1 may be TDD UL/DL configuration 0 and TDD UL/DL configuration 2 may be the second TDD UL/DL configuration 46 that is identified and signaled to the mobile terminal 10 by the apparatus 20 embodied by the access point 12, such as the processor 24 and/or the communication interface 28. As shown, TDD UL/DL configuration 2 differs from TDD UL/DL configuration 0 in that subframes 3, 4, 8 and 9
20 are UL subframes as defined by TDD UL/DL configuration 0, but are DL subframes as defined by TDD UL/DL configuration 2. Thus, subframes 3, 4, 8 and 9 of the resulting TDD UL/DL configuration 48 are flexible subframes that will be treated as DL subframes consistent with the second TDD UL/DL configuration going forward, while subframes 0 and 5 being DL subframes and subframes 2 and 7 being UL subframes. Continuing with
25 this example, since the mobile terminal has been informed that the second TDD UL/DL configuration is TDD UL/DL configuration 2, a mobile terminal that detects a DL grant in subframe 4 but not in subframe 3 may still treat both subframes 3 and 4 as DL

subframes, such as by measuring the CSI for subframes 3 and 4, rather than only for subframe 4.

[0055] In the foregoing examples, the second TDD UL/DL configuration 42, 46 was different than the first TDD UL/DL configuration 40. In an embodiment in which the

5 first and second TDD UL/DL configurations are identical, however, the identification of the second TDD UL/DL configuration to be the same as the first TDD UL/DL configuration and the signaling of the same, second TDD UL/DL configuration to the mobile terminal 10 may effectively disable flexible TDD UL/DL configuration. Thus, the apparatus 20 embodied by the access point 12 may also include means, such as the
10 processing circuitry 22, the processor 24, the communications interface 28 or the like, for disabling flexible TDD UL/DL configuration in an instance in which the first and second TDD UL/DL configurations are identical.

[0056] As shown in block 36 of Figure 3, the apparatus 20 embodied by the access point 12 may also include means, such as the processing circuitry 22, the processor 24,

15 the communications interface 28 or the like, for causing the one or more second TDD UL/DL configurations that have been identified to be signaled to another access point. Additionally or alternatively, the apparatus embodied by the access point may include means, such as the processing circuitry, the processor, the communications interface or the like, for receiving information from a mobile terminal 10 regarding one or more TDD
20 UL/DL configuration candidates of a neighboring access point. In this regard, the apparatus embodied by the access point, such as the processor and/or communications interface, may request information regarding the TDD UL/DL configuration candidates of a neighboring access point from the mobile terminal in order to initiate the provision of such information from the mobile terminal.

25 [0057] With reference now to Figure 6 from the perspective of a mobile terminal 10, the apparatus 20 embodied by the mobile terminal may include means, such as the processing circuitry 22, the processor 24 or the like, for determining a first TDD UL/DL

configuration based upon system information. See block 50. As described above, various types of system information may identify the first TDD UL/DL configuration including, for example, SIB1.

[0058] Referring to block 52 of Figure 6, the apparatus 20 embodied by the mobile terminal 10 may also include means, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for receiving an indication of one or more second TDDUL/DL configurations from among one or more TDDUL/DL configuration candidates associated with the first TDDUL/DL configuration that is based upon system information. Although the apparatus, such as the processor and/or the communications interface, may receive the indication of the one or more second TDDUL/DL configuration in various manners, the indication of one or more second TDDUL/DL configurations may be received, for example, via higher layer signaling, such as RRC, MIB or SIB signaling. The apparatus of this embodiment also includes means, such as the processing circuitry, the processor or the like, for identifying one of the second TDD UL/DL configurations to be utilized, such as based upon DL control channel detection, and means, such as the processing circuitry, the processor or the like, for thereafter operating in accordance with the second TDDUL/DL configuration that has been identified. See blocks 54 and 56.

[0059] As noted above, in an instance in which the second TDD UL/DL configuration is identical to the first TDDUL/DL configuration, the apparatus 20 embodied by the mobile terminal 10 may also include means, such as a processing circuitry 22, the processor 24 or the like, for determining that the flexible TDDUL/DL configuration is disabled. In one embodiment, the apparatus embodied by the mobile terminal may also include means, such as the processing circuitry, the processor, the communications interface 28 or the like, for causing information to be provided regarding one or more TDD UL/DL configuration candidates of a neighboring access point. See block 58 of Figure 6. For example, the apparatus, such as the processor and/or the

communication interface, may provide the information regarding one or more TDD UL/DL configuration candidates of a neighboring access point in response to a request from the access point 12 that is currently supporting the mobile terminal.

[0060] In order to reduce or eliminate loss associated with changes to the HARQ

5 timeline, the apparatus 20 embodied by the mobile terminal 10 may also include means, such as the processing circuitry 22, the processor 24 or the like, for determining at least one of a UL or a DL HARQ timeline and, in one embodiment, both a UL and a DL HARQ timeline, based upon one or more second TDD UL/DL configurations. See block 59 of Figure 6. In this regard, the apparatus embodied by the mobile terminal, such as the
10 processor, may be configured to implicitly derive a reference TDDUL/DL configuration for the UL and/or DL HARQ timeline from the signaling provided by the access point 12 based upon one or more predefined rules. In one embodiment, the apparatus embodied by the mobile terminal may include means, such as the processing circuitry, the processor or the like, for determining a reference TDD UL/DL configuration for the UL HARQ
15 timeline that contains the common DL subframe(s) shared by the one or more second TDD UL/DL configurations. In this regard, the apparatus, such as the processor, may determine the subframes that are designated to be DL subframes by each of the second TDD UL/DL configurations and may then adapt the UL HARQ timeline to the UL HARQ timeline of the determined reference TDD UL/DL configuration.

20 Correspondingly, the apparatus embodied by the mobile terminal may also include means, such as the processing circuitry, the processor or the like, for determining a reference TDD UL/DL configuration for the DL HARQ timeline that contains the common UL subframe(s) shared by the one or more second TDD UL/DL configurations. In this regard, the apparatus, such as the processor, may determine the subframes that are
25 designated to be UL subframes by each of the second TDD UL/DL configurations and may then adapt the DL HARQ timeline to the DL HARQ timeline of the determined reference TDD UL/DL configuration.

[0061] In one embodiment, the UL and/or the DL HARQ timelines may also be required to be one of the predefined TDD UL/DL configurations, such as those specified by TS36.211. The apparatus 20 embodied by the mobile terminal 10 may then operate in accordance with the UL and/or DL HARQ timeline that has been determined until the

5 apparatus embodied by the mobile terminal receives a different indication of one or more second TDD UL/DL configurations or until the access point 12 otherwise indicates that the UL and/or DL HARQ timeline that has been determined has expired, such as by the establishment of an effective time period for the UL and/or DL HARQ timeline.

[0062] By way of example, the access point 12 may provide an indication that the

10 second TDD UL/DL configurations are TDD UL/DL configurations A, B and C such that the TDD UL/DL configuration will only be reconfigured to be one of TDD UL/DL configurations A, B and C during the next period. Based upon a predefined rule, such as the identification of common UL and DL subframes, the apparatus 20 embodied by the mobile terminal 10 may determine a reference TDD UL/DL configuration to serve as the

15 HARQ timeline. More particularly, the apparatus, such as the processor 24, may determine reference TDD UL/DL configuration X to support UL HARQ operation with TDD UL/DL configuration X containing the common DL subframes of TDD UL/DL configurations A, B and C. Correspondingly, the apparatus, such as the processor, may determine reference TDD UL/DL configuration Y to support DL HARQ operation with

20 TDD UL/DL configuration Y containing the common UL subframes of TDD UL/DL configurations A, B and C. As such, the method, apparatus and computer program product of this example embodiment can establish a HARQ timeline that is consistent with the TDDUL/DL configuration of the mobile terminal so as to avoid loss or other inefficiencies associated with the establishment of the HARQ timeline as the TDDUL/DL

25 configurations may change. By determining the HARQ timeline implicitly based upon signaling otherwise provided by the access point, the method, apparatus and computer

program product of an example embodiment may avoid unnecessarily adding to the signaling overhead and the creation of additional error case handling.

[0063] In another embodiment, the reference configuration for the HARQ timeline may be explicitly signaled by the access point 12 to the mobile terminal 10. As shown in

5 block 60 of Figure 7, the apparatus 20 embodied by the access point may include mean, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for causing a reference configuration for at least one of a UL HARQ timeline or a DL HARQ timeline to be signaled. The reference configuration may be signaled in various manners including higher layer signaling, such as RRC signaling. In addition to

10 providing the reference configuration, the apparatus embodied by the access point may also include means, such as the processing circuitry, the processor, the communications interface or the like, for causing an effective period for the reference configuration to be signaled. See block 62. In this regard, the effective period defines the length of time that the reference configuration will be effective.

15 [0064] In one embodiment, however, the apparatus 20 embodied by the access point 12 may include means, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for causing another reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline to be signaled during the effective period. See block 64 of Figure 7. In this embodiment, the signaling of

20 another reference configuration during the effective period of a prior reference configuration causes the mobile terminal 10 to alter the respective HARQ timeline.

Alternatively, at the conclusion of the effective period, the mobile terminal may switch or fall back from the reference configuration of the UL and/or DL HARQ timeline to the ongoing TDDUL/DL configuration that has otherwise been established between the

25 access point and the mobile terminal.

[0065] From the perspective of the mobile terminal 10, an apparatus 20 embodied by the mobile terminal may communicate with the access point 12 in order to establish the

UL and/or DL HARQ timeline based upon explicit signaling from the access point. In this regard, the apparatus embodied by the mobile terminal may include means, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for receiving an indication of a reference configuration for at least one of a UL HARQ
5 timeline or a DL HARQ timeline. See block 70 of Figure 8. In addition, the apparatus embodied by the mobile terminal may include means, such as the processing circuitry, the processor, the communications interface or the like, for receiving an indication of an effective period for the reference configuration. See block 72. The apparatus embodied by the mobile terminal, such as the processor and/or the communications interface, may
10 receive the indication of the reference configuration and/or the indication of the effective period via a variety of different types of signaling including higher layer signaling, such as RRC signaling.

[0066] The apparatus 20 embodied by the mobile terminal 10 may also include means, such as the processing circuitry 22, the processor 24 or the like, for operating in
15 accordance with the reference configuration for at least the UL HARQ timeline and/or DL HARQ timeline during the effective period. See block 74. Since the reference configuration for the UL HARQ timeline and/or the DL HARQ timeline may be established based upon the various TDDUL/DL configurations that may be employed during the effective period, the loss or other inefficiencies associated with changes to the
20 HARQ timeline may be reduced or eliminated. In this regard, the apparatus embodied by the mobile terminal, such as the processor, may be configured to operate in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period regardless of the TDD UL/DL configuration otherwise established between the access point 12 and the mobile terminal. Thus, the UL
25 and/or DL HARQ timeline does not change during the effective configuration as the TDDUL/DL configuration changes so as to reduce or eliminate loss or inefficiencies otherwise associated with the change in the HARQ timeline

[0067] As noted above, the reference configuration for the UL HARQ timeline and/or DL HARQ timeline may be changed prior to expiration of the effective period. In this embodiment, the apparatus 20 embodied by the mobile terminal 10 may include means, such as the processing circuitry 22, the processor 24, the communications interface 28 or the like, for receiving another reference configuration for at least one of the UL HARQ timelines and/or the DL HARQ timeline during the effective period. In this embodiment, the apparatus embodied by the mobile terminal may also include means, such as the processing circuitry, the processor or the like, for thereafter operating in accordance with the other reference configuration for at least one of the UL HARQ timeline and/or the DL HARQ timeline. However, in an instance in which the reference configuration for the UL and/or DL HARQ timeline is not changed during the effective period, the apparatus 20 embodied by the mobile terminal 10 may also include means, such as the processing circuitry 22, the processor 24 or the like, for operating in accordance with an ongoing TDD UL/DL configuration established between the access point 12 and the mobile terminal for at least one and, more typically, both of the UL HARQ timeline and the DL HARQ timeline following expiration of the effective period. See block 76 of Figure 8.

[0068] By way of example, the initial TDD UL/DL configuration may be established, such as by signaling provided by SIB2, to be TDD UL/DL configuration A. Additionally, the access point 12 may identify the TDD UL/DL configurations for the next three frames n, n+1 and n+2 to be TDD UL/DL configurations B, C and D, respectively. In addition, the access point may provide an indication to the mobile terminal 10 that the DL HARQ timeline and the UL HARQ timeline will be X and Y, respectively. Thus, as the TDD UL/DL configuration for the access point and the mobile terminal transitions from TDD UL/DL configuration A to TDD UL/DL configurations B, C and D in frames n, n+1 and n+2, respectively, the DL HARQ timeline will remain as X and UL HARQ timeline will remain as Y.

[0069] By establishing the HARQ timeline, such as a UL HARQ timeline and/or the DL HARQ timeline, either explicitly or implicitly as described above, the HARQ timeline need not necessarily change as the TDD UL/DL configuration changes so as to reduce operational loss associated with the HARQ timeline. Additionally, the method, apparatus and computer program product of this example embodiment may provide reconfiguration flexibility with respect to the TDD UL/DL configuration, may avoid unnecessary control signaling overhead, may limit HARQ delay and may reduce feedback bundling loss.

[0070] As described above, Figures 3 and 6-8 are flowcharts illustrating the operations performed by a method, apparatus and computer program product, such as apparatus 20 of Figure 2, from the perspective of the mobile terminal 10 in conjunction with Figures 6 and 8 and a network entity, such as the access point 12, respectively, in conjunction with Figures 3 and 7 in accordance with one embodiment of the present invention. It will be understood that each block of the flowcharts, and combinations of blocks in the flowcharts, may be implemented by various means, such as hardware, firmware, processor, circuitry and/or other device associated with execution of software including one or more computer program instructions. For example, one or more of the procedures described above may be embodied by computer program instructions. In this regard, the computer program instructions which embody the procedures described above may be stored by a memory 26 of an apparatus employing an embodiment of the present invention and executed by a processor 24 of the apparatus. As will be appreciated, any such computer program instructions may be loaded onto a computer or other programmable apparatus (e.g., hardware) to produce a machine, such that the resulting computer or other programmable apparatus provides for implementation of the functions specified in the flowchart blocks. These computer program instructions may also be stored in a non-transitory computer-readable storage memory that may direct a computer or other programmable apparatus to function in a particular manner, such that the

instructions stored in the computer-readable storage memory produce an article of manufacture, the execution of which implements the function specified in the flowchart blocks. The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operations to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer or other programmable apparatus provide operations for implementing the functions specified in the flowchart blocks. As such, the operations of Figures 3 and 6-8, when executed, convert a computer or processing circuitry into a particular machine configured to perform an example embodiment of the present invention. Accordingly, the operations of Figures 3 and 6-8 define an algorithm for configuring a computer or processing circuitry 22, e.g., processor, to perform an example embodiment. In some cases, a general purpose computer may be provided with an instance of the processor which performs the algorithm of Figures 3 and 6-8 to transform the general purpose computer into a particular machine configured to perform an example embodiment.

[0071] Accordingly, blocks of the flowcharts support combinations of means for performing the specified functions and combinations of operations for performing the specified functions. It will also be understood that one or more blocks of the flowcharts, and combinations of blocks in the flowcharts, can be implemented by special purpose hardware-based computer systems which perform the specified functions, or combinations of special purpose hardware and computer instructions.

[0072] In some embodiments, certain ones of the operations above may be modified or further amplified as described below. Moreover, in some embodiments additional optional operations may also be included as shown, for example by the dashed lines in Figures 3 and 6-8. It should be appreciated that each of the modifications, optional additions or amplifications below may be included with the operations above either alone or in combination with any others among the features described herein.

[0073] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the

5 specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Moreover, although the foregoing descriptions and the associated drawings describe example embodiments in the context of certain example combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions may be provided by

10 alternative embodiments without departing from the scope of the appended claims. In this regard, for example, different combinations of elements and/or functions than those explicitly described above are also contemplated as may be set forth in some of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A method comprising:
identifying one or more second time division duplex (TDD) uplink
5 (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration
candidates associated with a first TDD UL/DL configuration that has been previously
configured by system information;
causing the one or more second TDD UL/DL configurations that have been
identified to be signaled to a mobile terminal; and
10 thereafter operating in accordance with a second TDD UL/DL configuration that
has been identified.
2. A method according to Claim 1 further comprising disabling flexible TDD
UL/DL configuration in an instance in which the first and second TDD UL/DL
15 configurations are identical.
3. A method according to any one of Claims 1 or 2 wherein causing the one or more
second TDD UL/DL configurations to be signaled to a mobile terminal comprises
causing the one or more second TDD UL/DL configurations to be signaled via higher
20 layer signaling.
4. A method according to any one of Claims 1 to 3 further comprising causing the
one or more second TDD UL/DL configurations that have been identified to be signaled
to another access point.
25
5. A method according to any one of Claims 1 to 4 further comprising receiving
information from the mobile terminal regarding one or more TDD UL/DL configuration
candidates of a neighboring access point.

6. An apparatus comprising:
at least one processor; and
at least one memory including computer program code, the at least one memory
and the computer program code configured to, with the at least one processor, cause the
5 apparatus at least to perform:

identifying one or more second time division duplex (TDD) uplink
(UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration
candidates associated with a first TDD UL/DL configuration that has been previously
configured by system information;

10 causing the one or more second TDD UL/DL configurations that have been
identified to be signaled to a mobile terminal; and
thereafter operating in accordance with a second TDD UL/DL configuration that
has been identified.

15 7. An apparatus according to Claim 6 wherein the at least one memory and the
computer program code are further configured to, with the at least one processor, cause
the apparatus to disable flexible TDD UL/DL configuration in an instance in which the
first and second TDD UL/DL configurations are identical.

20 8. An apparatus according to any one of Claims 6 or 7 wherein the at least one
memory and the computer program code are configured to, with the at least one processor,
cause the apparatus to cause the one or more second TDD UL/DL configurations to be
signaled to a mobile terminal via higher layer signaling.

25 9. An apparatus according to any one of Claims 6 to 8 wherein the at least one
memory and the computer program code are further configured to, with the at least one
processor, cause the apparatus to cause the one or more second TDD UL/DL
configurations that have been identified to be signaled to another access point.

10. An apparatus according to any one of Claims 6 to 9 wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to receive information from the mobile terminal regarding
5 one or more TDD UL/DL configuration candidates of a neighboring access point.

11. An apparatus according to any one of Claims 6 to 10 wherein the apparatus is embodied as an access point.

10 12. An apparatus according to any one of Claims 6 to 11 wherein the apparatus is configured for use in an Long Term Evolution (LTE) system.

13. An apparatus according to any one of Claims 6 to 12 further comprising a communications interface configured to communicate with the mobile terminal.
15

14. A computer program product comprising at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein, the computer-executable program code portions comprising program code instructions for:

20 identifying one or more second time division duplex (TDD) uplink (UL)/downlink (DL) configurations from among one or more TDD UL/DL configuration candidates associated with a first TDD UL/DL configuration that has been previously configured by system information;
causing the one or more second TDD UL/DL configurations that have been
25 identified to be signaled to a mobile terminal; and
thereafter operating in accordance with a second TDD UL/DL configuration that has been identified.

15. A method comprising:

determining a first time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information;

5 receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information;

identifying one of the one or more second TDD UL/DL configurations; and

thereafter operating in accordance with the second TDD UL/DL configuration that has been identified.

10

16. A method according to Claim 15 further comprising determining that flexible TDD UL/DL configuration is disabled in an instance in which the first and second TDD UL/DL configurations are identical.

15 17. A method according to any one of Claims 15 or 16 wherein receiving an indication of one or more second TDD UL/DL configurations comprises receiving the one or more second TDD UL/DL configurations via higher layer signaling.

18. A method according to any one of Claims 15 to 17 further comprising causing
20 information to be provided regarding one or more TDD UL/DL configuration candidates of a neighboring access point.

19. A method according to any one of Claims 15 to 18 further comprising
determining at least one of an UL or a DL hybrid automatic repeat request (HARQ)
25 timeline based on the one or more second TDD UL/DL configurations.

20. A method according to Claim 19 wherein determining at least one of an UL or a DL HARQ timeline comprises determining an UL HARQ timeline based upon common DL subframe(s) shared by the one or more second TDD UL/DL configurations.

5 21. A method according to Claim 19 wherein determining at least one of an UL or a DL HARQ timeline comprises determining a DL HARQ timeline based upon common UL subframe(s) shared by the one or more second TDD UL/DL configurations.

22. An apparatus comprising:

10 at least one processor; and

at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform:

15 determining a first time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information;

receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information;

20 identifying one of the one or more second TDD UL/DL configurations; and thereafter operating in accordance with the second TDD UL/DL configuration that has been identified.

23. An apparatus according to Claim 22 wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause
25 the apparatus to determine that flexible TDD UL/DL configuration is disabled in an instance in which the first and second TDD UL/DL configurations are identical.

24. An apparatus according to any one of Claims 22 or 23 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to receive an indication of one or more second TDD UL/DL configurations via higher layer signaling.

5

25. An apparatus according to any one of Claims 22 to 24 wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to cause information to be provided regarding one or more TDD UL/DL configuration candidates of a neighboring access point.

10

26. An apparatus according to any one of Claims 22 to 25 wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to determine at least one of an UL or a DL hybrid automatic repeat request (HARQ) timeline based on the one or more second TDD UL/DL configurations.

15

27. An apparatus according to Claim 26 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to determine at least one of an UL or a DL HARQ timeline by determining an UL HARQ timeline based upon common DL subframe(s) shared by the one or more second TDD UL/DL configurations.

20

28. An apparatus according to Claim 26 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to determine at least one of an UL or a DL HARQ timeline by determining an DL HARQ timeline based upon common UL subframe(s) shared by the one or more second TDD UL/DL configurations.

25

29. An apparatus according to any one of Claims 22 to 28 wherein the apparatus is embodied as a mobile terminal.

30. An apparatus according to any one of Claims 22 to 29 wherein the apparatus is
5 configured for use in an Long Term Evolution (LTE) system.

31. An apparatus according to any one of Claims 22 to 30 further comprising user interface circuitry configured to facilitate user control of at least some functions based upon user input.

10

32. A computer program product comprising at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein, the computer-executable program code portions comprising program code instructions for:

15

determining a first time division duplex (TDD) uplink (UL)/downlink (DL) configuration based upon system information;

receiving an indication of one or more second TDD UL/DL configurations from among one or more TDD UL/DL configuration candidates associated with the first TDD UL/DL configuration that is based upon system information;

20

identifying one of the one or more second TDD UL/DL configurations; and thereafter operating in accordance with the second TDD UL/DL configuration that has been identified.

33. A method comprising:

25

causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled; and causing an effective period for the reference configuration to be signaled.

34. A method according to Claim 33 wherein causing the reference configuration to be signaled comprises causing the reference configuration to be signaled via radio resource control (RRC) signaling.

5 35. A method according to any one of Claims 33 or 34 further comprising causing another reference configuration for at least one of an uplink HARQ timeline or a downlink HARQ timeline to be signaled during the effective period in order to alter the respective HARQ timeline.

10 36. An apparatus comprising:
at least one processor; and
at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus at least to perform:

15 causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled; and
causing an effective period for the reference configuration to be signaled.

37. An apparatus according to Claim 36 wherein the at least one memory and the
20 computer program code are configured to, with the at least one processor, cause the apparatus to cause the reference configuration to be signaled via radio resource control (RRC) signaling.

38. An apparatus according to any one of Claims 36 or 37 wherein the at least one
25 memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to cause another reference configuration for at least one of an uplink HARQ timeline or a downlink HARQ timeline to be signaled during the effective period in order to alter the respective HARQ timeline.

39. An apparatus according to any one of Claims 36 to 38 wherein the apparatus is embodied as an access point.

5 40. An apparatus according to any one of Claims 36 to 39 wherein the apparatus is configured for use in an Long Term Evolution (LTE) system.

41. An apparatus according to any one of Claims 36 to 40 further comprising a communications interface configured to communicate with the mobile terminal.

10

42. A computer program product comprising at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein, the computer-executable program code portions comprising program code instructions for:

15 causing a reference configuration for at least one of an uplink hybrid automatic repeat request (HARQ) timeline or a downlink HARQ timeline to be signaled; and causing an effective period for the reference configuration to be signaled.

43. A method comprising:

20 receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline;

receiving an indication of an effective period for the reference configuration; and operating in accordance with the reference configuration for at least one of the UL

25 HARQ timeline or the DL HARQ timeline during the effective period.

44. A method according to Claim 43 wherein receiving the indication of a reference configuration comprises receiving the reference configuration via radio resource control (RRC) signaling.

- 5 45. A method according to any one of Claims 43 or 44 further comprising:
receiving another reference configuration for at least one of an UL HARQ
timeline or a DL HARQ timeline during the effective period; and
thereafter operating in accordance with the another reference configuration for at
least one of the UL HARQ timeline or the DL HARQ timeline.

10

46. A method according to any one of Claims 43 or 44 further comprising operating
in accordance with an ongoing time division duplex (TDD) UL/DL configuration for at
least one of the UL HARQ timeline or the DL HARQ timeline following the effective
period.

15

47. A method according to any one of Claims 43 or 44 wherein operating in
accordance with the reference configuration during the effective period comprises
operating in accordance with the reference configuration for at least one of the UL
HARQ timeline or the DL HARQ timeline during the effective period regardless of a
20 time division duplex (TDD) UL/DL configuration.

20

48. An apparatus comprising:
at least one processor; and
at least one memory including computer program code, the at least one memory
25 and the computer program code configured to, with the at least one processor, cause the
apparatus at least to perform:

receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline;

receiving an indication of an effective period for the reference configuration; and
5 operating in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.

49. An apparatus according to Claim 48 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the
10 apparatus to receive the indication of a reference configuration via radio resource control (RRC) signaling.

50. An apparatus according to any one of Claims 48 or 49 wherein the at least one memory and the computer program code are further configured to, with the at least one
15 processor, cause the apparatus to:

receive another reference configuration for at least one of an UL HARQ timeline or a DL HARQ timeline during the effective period; and

thereafter operate in accordance with the another reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline.

20

51. An apparatus according to any one of Claims 48 or 49 wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to operate in accordance with an ongoing time division duplex (TDD) UL/DL configuration for at least one of the UL HARQ timeline or the DL
25 HARQ timeline following the effective period.

52. An apparatus according to any one of Claims 48 or 49 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to operate in accordance with the reference configuration during the effective period by operating in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period
5 regardless of a time division duplex (TDD) UL/DL configuration.

53. An apparatus according to any one of Claims 48 to 52 wherein the apparatus is embodied as a mobile terminal.

10

54. An apparatus according to any one of Claims 48 to 53 wherein the apparatus is configured for use in an Long Term Evolution (LTE) system.

55. An apparatus according to any one of Claims 48 to 54 further comprising user interface circuitry configured to facilitate user control of at least some functions based upon user input.
15

56. A computer program product comprising at least one non-transitory computer-readable storage medium having computer-executable program code portions stored therein, the computer-executable program code portions comprising program code instructions for:
20

receiving an indication of a reference configuration for at least one of an uplink (UL) hybrid automatic repeat request (HARQ) timeline or a downlink (DL) HARQ timeline;

25 receiving an indication of an effective period for the reference configuration; and operating in accordance with the reference configuration for at least one of the UL HARQ timeline or the DL HARQ timeline during the effective period.

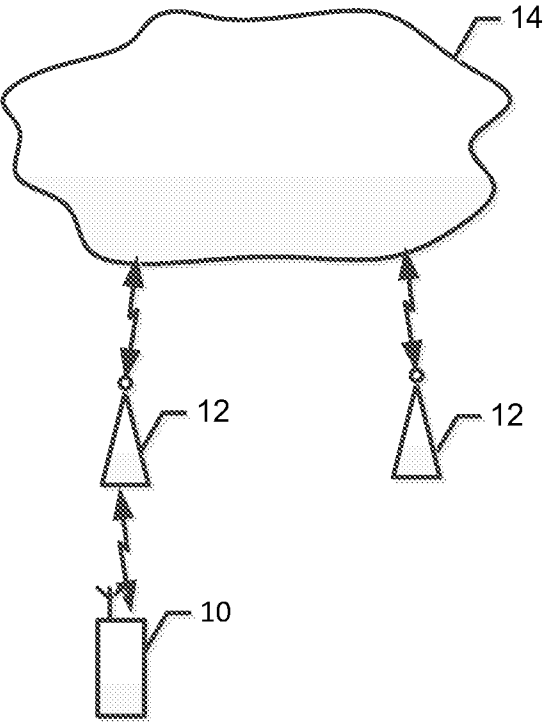


FIG. 1

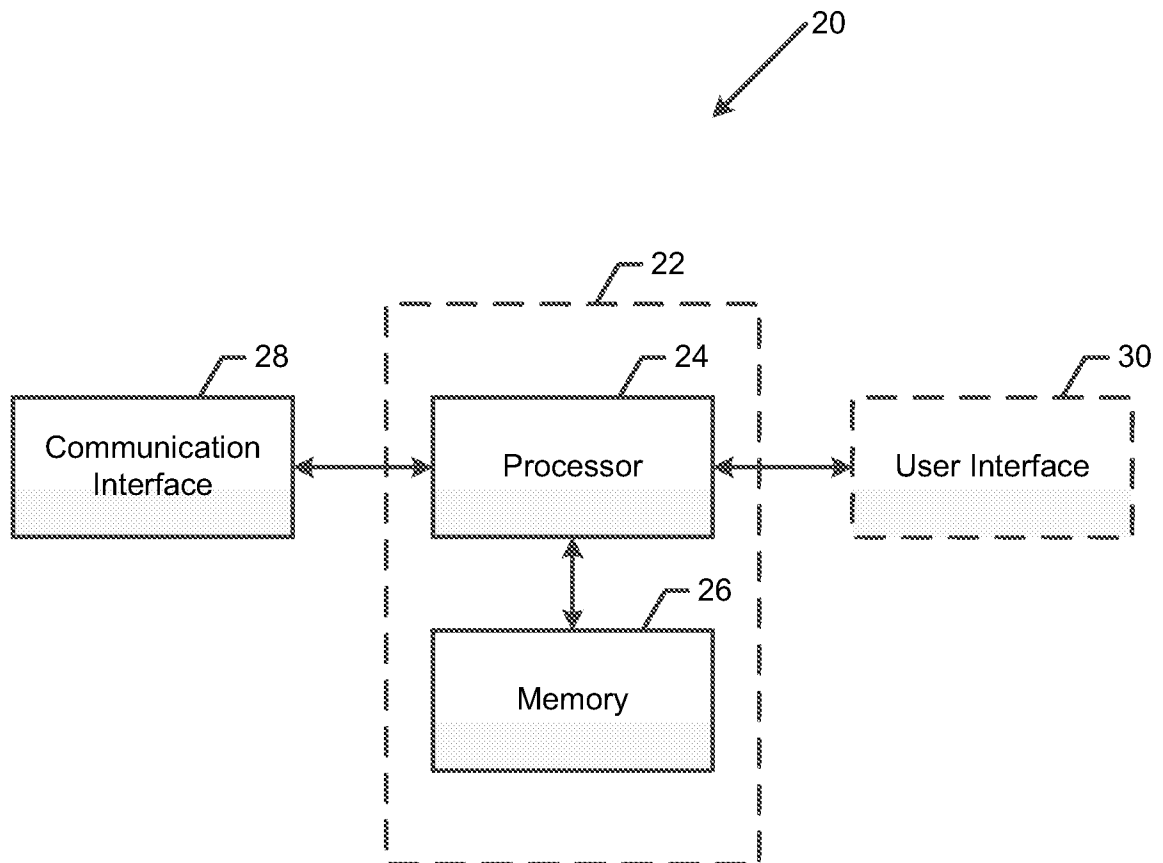


FIG. 2

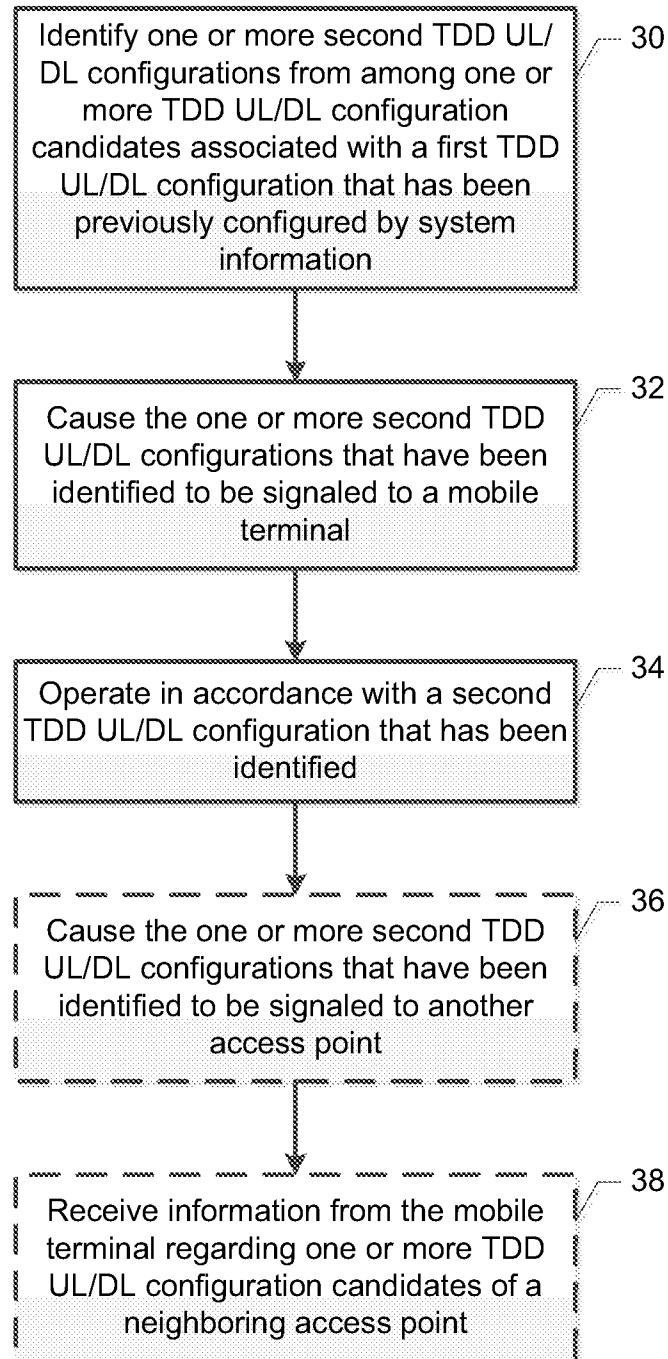


FIG. 3

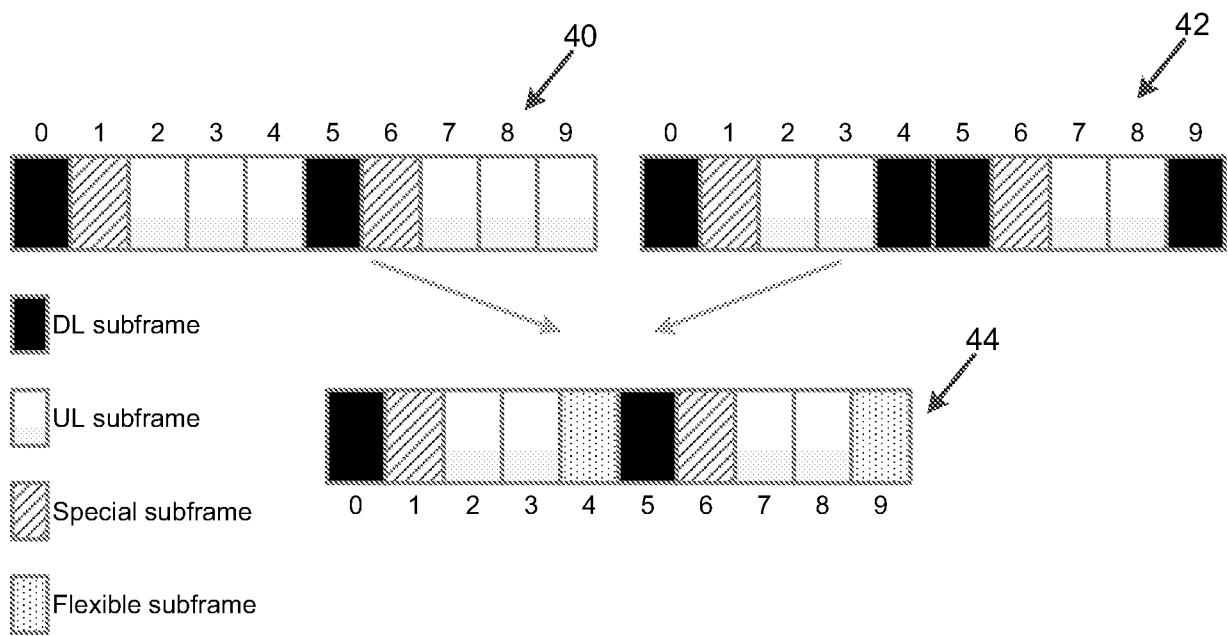


FIG. 4

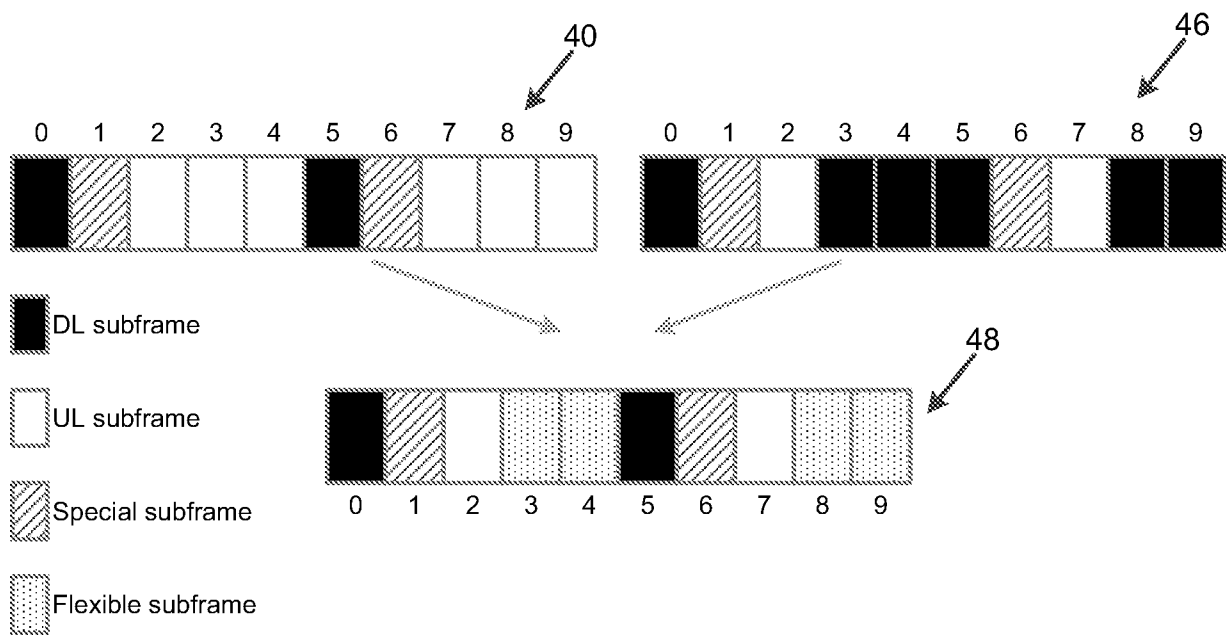


FIG. 5

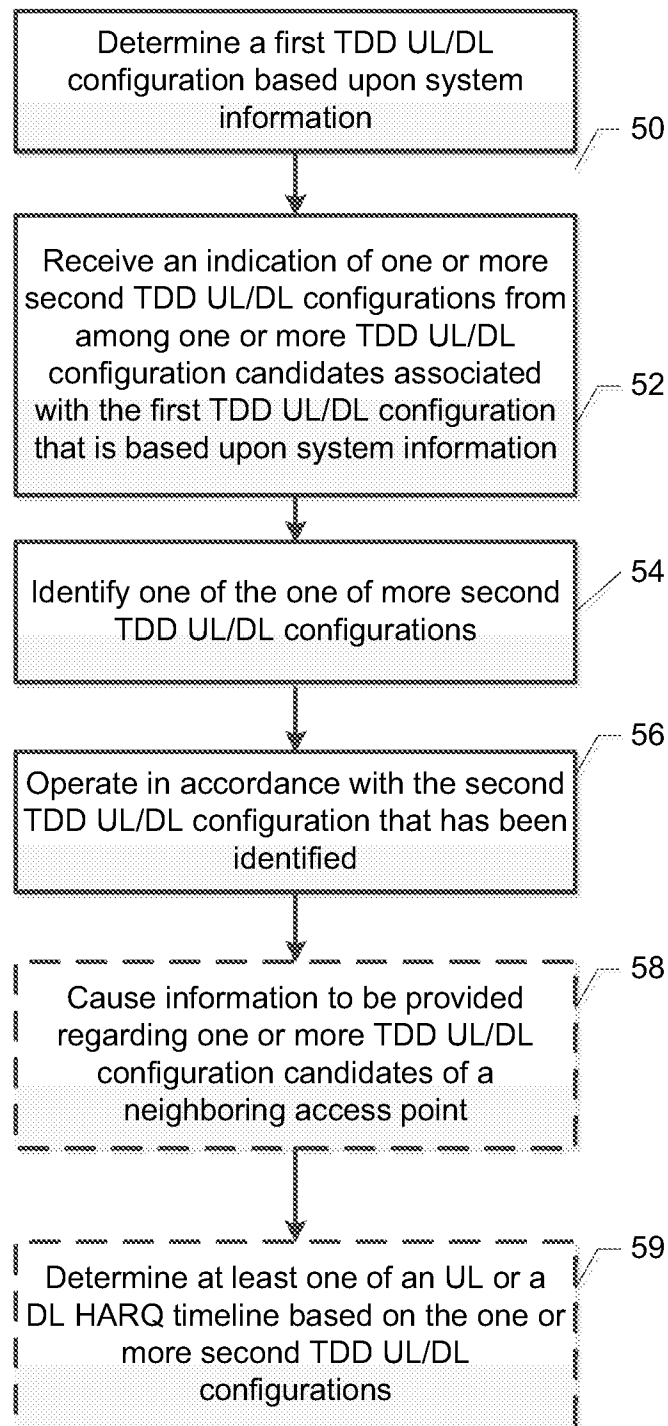


FIG. 6

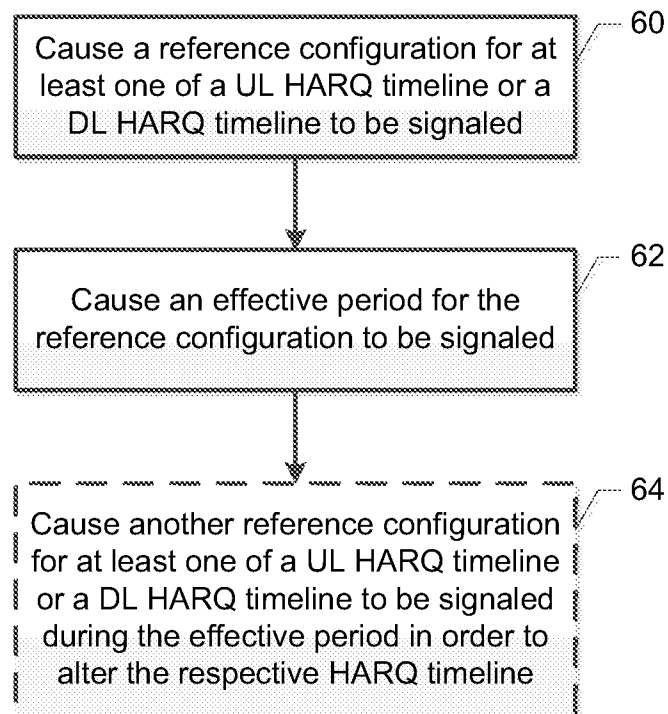


FIG. 7

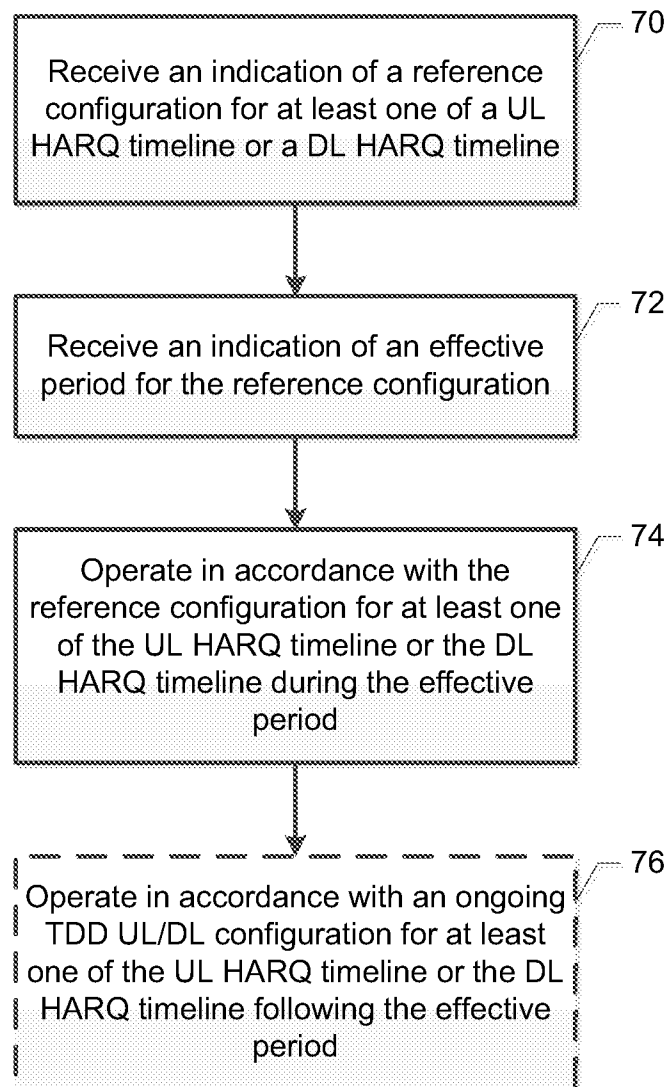


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2013/070704

A. CLASSIFICATION OF SUBJECT MATTER

H04W 40/00 (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)

IPC: H04W, H04L, G06F

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)

SIPOABS, time division duplex, uplink, downlink, configuration, identify, TDD, UL, DL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN102638798A (NEW POSTCOM EQUIPMENT CO., LTD.) 15 Aug. 2012 (15.08.2012) see the whole document	1-56
A	WO2012/012583A1 (QUALCOMM INCORPORATED) 26 Jan. 2012 (26.01.2012) see the whole document	1-56
A	CN102075949A (DATANG MOBILE COMMUNICATIONS EQUIPMENT CO., LTD.) 25 May 2011 (25.05.2011) see the whole document	1-56

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	“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
“A” document defining the general state of the art which is not considered to be of particular relevance	“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
“E” earlier application or patent but published on or after the international filing date	“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
“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)	“&” document member of the same patent family
“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	

Date of the actual completion of the international search 17 Oct. 2013 (17.10.2013)	Date of mailing of the international search report 31 Oct. 2013 (31.10.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer WANGKe Telephone No. (86-10)62412028

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/070704

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN102638798A	15.08.2012	NONE	
WO2012/012583A1	26.01.2012	KR2013043201A	29.04.2013
		US2012020258A1	26.01.2012
		EP2596655A1	29.05.2013
CN102075949A	25.05.2011	WO2012083811A1	28.06.2012
		CN102075949B	20.03.2013