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(54) **Title**: UCI SHIFT AND NEW PUSCH TIMING TO COMBAT DL-UL INTERFERENCE IN EIMTA

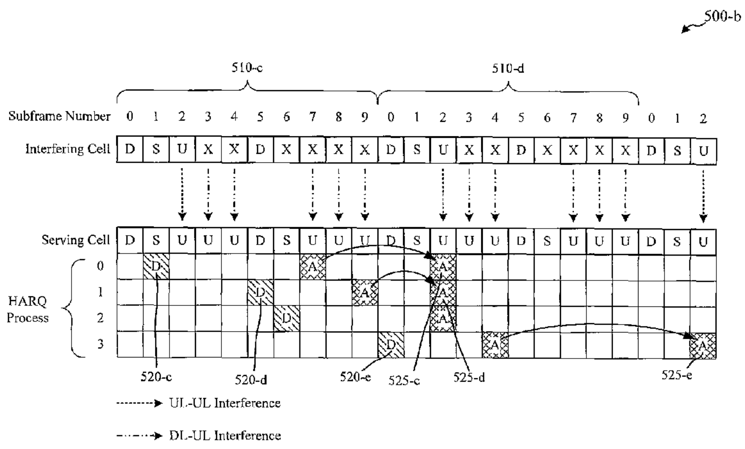

FIG. 5B

(57) **Abstract**: The effects of downlink-to-uplink interference are mitigated in TDD systems by adapting timing for uplink control information and UL HARQ retransmission. In some embodiments, uplink control information may be shifted to subframes that experience lower downlink interference from other cells. In some embodiments, UL HARQ timing is modified such that UL transmissions and retransmissions experience similar interference profiles. In embodiments, asynchronized UL HARQ may be used to schedule retransmissions in UL subframes with similar interference profiles as the original transmission (e.g., either UL-UL interference or DL-UL interference, etc.). In other embodiments, modified synchronous UL HARQ timing adapts retransmission to occur on UL subframes with similar interference profiles as the transmission based on the TDD UL-DL configuration of the serving cell and/or interfering cells.

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UCI SHIFT AND NEW PUSCH TIMING TO COMBAT DL-UL INTERFERENCE IN EIMTA

BACKGROUND

[0001] Wireless communication networks are widely deployed to provide various communication services such as voice, video, packet data, messaging, broadcast, and the like. These wireless networks may be multiple-access networks capable of supporting multiple users by sharing the available network resources.

[0002] A wireless communication network may include a number of base stations that can support communication for a number of mobile devices. A mobile device may communicate with a base station via downlink (DL) and uplink (UL) transmissions. The downlink (or forward link) refers to the communication link from the base station to the mobile device, and the uplink (or reverse link) refers to the communication link from the mobile device to the base station.

[0003] Multiple access technologies may use Frequency Division Duplexing (FDD) or Time Division Duplexing (TDD) to provide uplink and downlink communications over one or more carriers. TDD operation offers flexible deployments without requiring paired spectrum resources. TDD formats include transmission of frames of data, each including a number of different subframes in which different subframes may be uplink or downlink subframes. In systems that operate using TDD, different formats may be used in which uplink and downlink communications may be asymmetric. Flexible DL/UL configuration provides efficient ways to use unpaired spectrum resources and UL/DL configuration may be adaptive based on traffic conditions (e.g., UL/DL loading at the base station and/or mobile device). However, flexible UL/DL configurations of base stations may cause increased interference between and among base stations and mobile devices.

SUMMARY

[0004] Described embodiments mitigate the effects of downlink-to-uplink interference in TDD systems by adapting timing for uplink control information and UL HARQ retransmission. In some embodiments, uplink control information (UCI) may be shifted to subframes that experience lower downlink interference from other cells. In instances where

TDD UL-DL configurations for neighboring cells are known, subframes for transmission of uplink control information may be selected based on common UL subframes between the TDD UL-DL configurations used for the serving cell and the neighboring cells. In instances where TDD UL-DL configurations for neighboring cells are unknown, subframes for transmission of uplink control information may be selected based on UL subframes common to available TDD UL-DL configurations. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UCI transmission performance with UL/DL flexibility.

[0005] In some embodiments UL HARQ timing is modified such that UL transmissions and retransmissions experience similar interference profiles. In embodiments, asynchronized UL HARQ may be used to schedule retransmissions in UL subframes with similar interference profiles as the original transmission (e.g., either UL-UL interference or DL-UL interference, etc.). In other embodiments, modified synchronous UL HARQ timing adapts retransmission to occur on UL subframes with similar interference profiles as the transmission based on the TDD UL-DL configuration of the serving cell. Where TDD UL-DL configurations for neighboring cells are known, the new UL HARQ timing may be based on the known TDD UL-DL configurations. Where TDD UL-DL configurations for neighboring cells are unknown, the new UL HARQ timing may select UL subframes for retransmissions experiencing similar interference profiles as the original transmission for all available TDD UL-DL configurations of the neighboring cells. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UL HARQ performance with UL/DL flexibility.

[0006] Embodiments are directed to a method for mitigating interference for TDD carriers in a wireless communications network. The method includes determining UCI for transmission to a serving cell during a first UL subframe, determining a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell, and transmitting the UCI in the reduced interference UL subframe. In some embodiments, determining the reduced interference UL subframe includes determining a serving TDD configuration of the serving cell, determining an interfering TDD configuration of the interfering network cell, and determining, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration. The interfering TDD configuration of the interfering network cell may be received from the interfering network cell. In some embodiments, determining the reduced interference UL subframe includes determining a serving TDD configuration of the serving cell, and determining the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations. The reduced interference UL subframe may be the third subframe of every 10 ms radio frame of an LTE type 2 frame structure.

[0007] Some embodiments are directed to a method for mitigating interference for TDD carriers in a wireless communications network. The method includes receiving, at a UE, a negative acknowledgement (NACK) from a serving cell associated with data transmitted by the UE in a first UL subframe, and selecting a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe. In some embodiments, determining the transmission direction of the interfering TDD carrier of the interfering cell for the first UL subframe includes receiving the TDD configuration of the interfering network cell associated with the interfering TDD carrier. In some embodiments, the retransmission UL subframe is an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier. The available TDD configurations of the interfering TDD carrier may be a subset of LTE type 2 frame structure TDD configurations. The method may include retransmitting the transmitted data in the selected retransmission UL subframe of the TDD carrier.

[0008] Embodiments are directed to a method for mitigating interference for TDD carriers in a wireless communications network including transmitting, from a serving cell, one or more data transmissions to a UE over one or more DL subframes, determining a reduced interference UL subframe for receiving UCI from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell, and decoding the UCI based on the reduced interference UL subframe. Determining the reduced interference UL subframe may include determining a serving TDD configuration of the serving cell, determining an interfering TDD configuration of the interfering cell, and determining, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration. In some embodiments, determining the reduced interference UL subframe includes determining a serving TDD configuration of the serving cell, determining the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

[0009] Embodiments are directed to a method for mitigating interference for TDD carriers in a wireless communications network including transmitting, to a UE, a NACK associated with data transmitted by the UE in a first UL subframe, and decoding a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0010] Embodiments are directed to an apparatus for mitigating interference for TDD carriers in a wireless communications network including means for determining UCI for transmission to a serving cell during a first UL subframe, means for determining a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell, and means for transmitting the UCI in the reduced interference UL subframe. The means for determining the reduced interference UL subframe may include means for determining a serving TDD configuration of the serving cell, means for determining an interfering TDD configuration of the interfering network cell, and means for determining, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration. The means for determining the reduced interference UL subframe may include means for determining a serving TDD configuration of the serving cell, and means for determining the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

[0011] Embodiments are directed to an apparatus for mitigating interference for TDD carriers in a wireless communications network including means for receiving, at UE, a NACK from a serving cell associated with data transmitted by the UE in a first UL subframe, and means for selecting a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0012] Embodiments are directed to an apparatus for mitigating interference for TDD carriers in a wireless communications network including means for transmitting, from a serving cell, one or more data transmissions to a UE over one or more DL subframes, means for determining a reduced interference UL subframe for receiving UCI from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell, and means for decoding the UCI based on the reduced interference UL subframe. The means for determining the reduced interference UL subframe may include means for determining a serving TDD configuration of the serving cell, means for determining an interfering TDD configuration of the interfering cell, and means for determining, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration. The means for determining the reduced interference UL subframe may include means for determining a serving TDD configuration of the serving cell, and means for determining the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

[0013] Embodiments are directed to an apparatus for mitigating interference for TDD carriers in a wireless communications network including means for transmitting, to a UE, a NACK associated with data transmitted by the UE in a first UL subframe, and means for decoding a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0014] Embodiments are directed to a computer program product for mitigating interference for TDD carriers in a wireless communications network including a non-transitory computer-readable medium including code for causing a computer to determine UCI for transmission to a serving cell during a first UL subframe, code for causing the computer to determine a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell, and code for causing the computer to transmit the UCI in the reduced interference UL subframe. The non-transitory computer-readable medium may include code for causing the computer to determine a serving TDD configuration of the serving cell, code for causing the computer to determine an interfering TDD configuration of the interfering network cell, and code for causing the computer to determine, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration. The non-transitory computer-readable medium may include code for causing the computer to determine a serving TDD configuration of the serving cell, and code for causing the computer to determine the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

[0015] Embodiments are directed to a computer program product for mitigating interference for TDD carriers in a wireless communications network including a non-transitory computer-readable medium including code for causing a computer to receive, at a UE, a NACK from a serving cell associated with data transmitted by the UE in a first UL subframe and code for causing the computer to select a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0016] Embodiments are directed to a computer program product for mitigating interference for TDD carriers in a wireless communications network including a non-transitory computer-readable medium including code for causing a computer to transmit, from a serving cell, one or more data transmissions to a UE over one or more DL subframes, code for causing the computer to determine a reduced interference UL subframe for receiving

UCI from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell, and code for causing the computer to decode the UCI based on the reduced interference UL subframe. The non-transitory computer-readable medium may include code for causing the computer to determine a serving TDD configuration of the serving cell, code for causing the computer to determine an interfering TDD configuration of the interfering cell, and code for causing the computer to determine, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration. The non-transitory computer-readable medium may include code for causing the computer to determine a serving TDD configuration of the serving cell, and code for causing the computer to determine the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

[0017] Embodiments are directed to a computer program product for mitigating interference for TDD carriers in a wireless communications network including a non-transitory computer-readable medium including code for causing a computer to transmit, to a UE, a NACK associated with data transmitted by the UE in a first UL subframe, and code for causing the computer to decode a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0018] Embodiments are directed to a communications device for mitigating interference for TDD carriers in a wireless communications network including at least one processor configured to determine UCI for transmission to a serving cell during a first UL subframe, determine a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell, and transmit the UCI in the reduced interference UL subframe. The at least one processor may be configured to determine a serving TDD configuration of the serving cell, determine an interfering TDD configuration of the interfering network cell, and determine, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration. The at least one processor may be configured to determine a serving TDD configuration of the serving cell, and determine the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

[0019] Embodiments are directed to a communications device for mitigating interference for TDD carriers in a wireless communications network including at least one processor configured to receive, at a UE, a NACK from a serving cell associated with data transmitted by the UE in a first UL subframe, and select a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmission UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

[0020] Embodiments are directed to a communications device for mitigating interference for TDD carriers in a wireless communications network including at least one processor configured to transmit, from a serving cell, one or more data transmissions to a UE over one or more DL subframes, determine a reduced interference UL subframe for receiving UCI from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell, and decode the UCI based on the reduced interference UL subframe. The at least one processor may be configured to determine a serving TDD configuration of the serving cell, determine an interfering TDD configuration of the interfering cell, and determine, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration. The at least one processor may be configured to determine a serving TDD configuration of the serving cell, and determine the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

[0021] Embodiments are directed to a communications device for mitigating interference for TDD carriers in a wireless communications network including at least one processor configured to transmit, to a UE, a NACK associated with data transmitted by the UE in a first UL subframe, and decode a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe. The retransmitted UL subframe may be an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] A further understanding of the nature and advantages of the present invention may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

[0023] FIG. 1 is a diagram illustrating an example of a wireless communications system in accordance with various embodiments;

[0024] FIG. 2 illustrates an example network environment using TDD carriers during a subframe where some TDD transmissions are UL and some are DL transmissions in accordance with various embodiments;

[0025] FIG. 3 is a timing diagram illustrating DL HARQ operation for two frames in a TDD system in accordance with various embodiments;

[0026] FIG. 4 is a timing diagram illustrating UL HARQ operation for two frames in accordance with various embodiments;

[0027] FIG. 5A is a timing diagram showing shifted UCI timing using known interfering cell TDD UL-DL configurations in accordance with various embodiments;

[0028] FIG. 5B is a timing diagram illustrating an alternative embodiment for UCI shifting where TDD UL-DL configurations for neighboring or potentially interfering cells are not known by the serving cell and/or UE;

[0029] FIG. 6A illustrates a method for shifting UCI at a UE to mitigate DL-UL interference in accordance with various embodiments;

[0030] FIG. 6B illustrates a method for shifting UCI at a serving cell to mitigate DL-UL interference in accordance with various embodiments;

[0031] FIG. 7A illustrates an alternative method for shifting UCI at a UE to mitigate DL-UL interference when UL-DL configurations for potentially interfering cells are unknown;

[0032] FIG. 7B illustrates an alternative method for shifting UCI at a serving cell to mitigate DL-UL interference when UL-DL configurations for potentially interfering cells are unknown;

[0033] FIG. 8A is a timing diagram illustrating modified synchronous UL HARQ timing in accordance with various embodiments;

[0034] FIG. 8B is a timing diagram illustrating another example of modified synchronous UL HARQ timing in accordance with various embodiments;

[0035] FIG. 8C is a timing diagram illustrating an alternative embodiment of modified synchronous UL HARQ timing where TDD UL-DL configurations for interfering cells are unknown;

[0036] FIG. 9A illustrates a method for performing modified synchronous UL HARQ timing in accordance with various embodiments;

[0037] FIG. 9B illustrates a method for performing modified synchronous UL HARQ timing in accordance with various embodiments;

[0038] FIG. 10 illustrates a system for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments;

[0039] FIG. 11 shows a block diagram of a design of DL HARQ/UCI processor of a UE in accordance with various embodiments;

[0040] FIG. 12 shows a block diagram of a design of UL HARQ processor of a UE in accordance with various embodiments;

[0041] FIG. 13 shows a block diagram of a design of DL HARQ/UCI processor of a serving cell in accordance with various embodiments;

[0042] FIG. 14 shows a block diagram of a design of UL HARQ processor of a serving cell in accordance with various embodiments;

[0043] FIG. 15 is a block diagram of a mobile device 115-e configured for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments; and

[0044] FIG. 16 shows a block diagram of a communications system 1600 that may be configured for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments.

DETAILED DESCRIPTION

[0045] Described embodiments are directed to systems and methods for mitigation of downlink-to-uplink interference in TDD systems by adapting timing for uplink control information and UL HARQ retransmission. In some embodiments, uplink control information may be shifted to subframes that experience lower downlink interference from other cells. In instances where TDD UL-DL configurations for neighboring cells are known, subframes for transmission of uplink control information may be selected based on common UL subframes between the TDD UL-DL configurations used for the serving cell and the neighboring cells. In instances where TDD UL-DL configurations for neighboring cells are unknown, subframes for transmission of uplink control information may be selected based on UL subframes common to available TDD UL-DL configurations. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UCI transmission performance with UL/DL flexibility.

[0046] In some embodiments UL HARQ timing is modified such that UL transmissions and retransmissions experience similar interference profiles. In embodiments, asynchronized UL HARQ may be used to schedule retransmissions in UL subframes with similar interference profiles as the original transmission (e.g., either UL-UL interference or DL-UL interference, etc.). In other embodiments, modified synchronous UL HARQ timing adapts retransmission to occur on UL subframes with similar interference profiles as the transmission based on the TDD UL-DL configuration of the serving cell. Where TDD UL-DL configurations for neighboring cells are known, the new UL HARQ timing may be based on the known TDD UL-DL configurations. Where TDD UL-DL configurations for neighboring cells are unknown, the new UL HARQ timing may select UL subframes for retransmissions experiencing similar interference profiles as the original transmission for all available TDD UL-DL configurations of the neighboring cells. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UL HARQ performance with UL/DL flexibility.

[0047] Techniques described herein may be used for various wireless communications systems such as cellular wireless systems, Peer-to-Peer wireless communications, wireless local access networks (WLANs), ad hoc networks, satellite communications systems, and other systems. The terms "system" and "network" are often used interchangeably. These wireless communications systems may employ a variety of radio communication technologies such as Code Division Multiple Access (CDMA), Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Orthogonal FDMA (OFDMA), Single-Carrier FDMA (SC-FDMA), and/or other radio technologies. Generally, wireless communications are conducted according to a standardized implementation of one or more radio communication technologies called a Radio Access Technology (RAT). A wireless communications system or network that implements a Radio Access Technology may be called a Radio Access Network (RAN).

[0048] Examples of Radio Access Technologies employing CDMA techniques include CDMA2000, Universal Terrestrial Radio Access (UTRA), etc. CDMA2000 covers IS-2000, IS-95, and IS-856 standards. IS-2000 Releases 0 and A are commonly referred to as CDMA2000 1X, 1X, etc. IS-856 (TIA-856) is commonly referred to as CDMA2000 1xEV-DO, High Rate Packet Data (HRPD), etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. Examples of TDMA systems include various implementations of Global System for Mobile Communications (GSM). Examples of Radio Access Technologies employing OFDM and/or OFDMA include Ultra Mobile Broadband (UMB), Evolved UTRA (E-UTRA), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are new releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A, and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). CDMA2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the systems and radio technologies mentioned above as well as other systems and radio technologies.

[0049] Thus, the following description provides examples, and is not limiting of the scope, applicability, or configuration set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the spirit and scope of the disclosure. Various embodiments may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to certain embodiments may be combined in other embodiments.

[0050] Referring first to **FIG. 1**, a diagram illustrates an example of a wireless communications system 100. The system 100 includes base stations (or cells) 105, communication devices 115, and a core network 130. The base stations 105 may communicate with the communication devices 115 under the control of a base station controller (not shown), which may be part of the core network 130 or the base stations 105 in various embodiments. Base stations 105 may communicate control information and/or user data with the core network 130 through backhaul links 132. Backhaul links 132 may be wired backhaul links (*e.g.*, copper, fiber, etc.) and/or wireless backhaul links (*e.g.*, microwave, etc.). In embodiments, the base stations 105 may communicate, either directly or indirectly, with each other over backhaul links 134, which may be wired or wireless communication links. The system 100 may support operation on multiple carriers (waveform signals of different frequencies). Multi-carrier transmitters can transmit modulated signals simultaneously on the multiple carriers. For example, each communication link 125 may be a multi-carrier signal modulated according to the various radio technologies described above. Each modulated signal may be sent on a different carrier and may carry control information (*e.g.*, reference signals, control channels, etc.), overhead information, data, etc.

[0051] The base stations 105 may wirelessly communicate with the devices 115 via one or more base station antennas. Each of the base station 105 sites may provide communication coverage for a respective coverage area 110. In some embodiments, base stations 105 may be referred to as a base transceiver station, a radio base station, an access point, a radio transceiver, a basic service set (BSS), an extended service set (ESS), a NodeB, eNodeB (eNB), Home NodeB, a Home eNodeB, or some other suitable terminology. The coverage area 110 for a base station may be divided into sectors making up only a portion of the coverage area (not shown). The system 100 may include base stations 105 of different types (*e.g.*, macro, micro, and/or pico base stations). There may be overlapping coverage areas for different technologies.

[0052] The wireless network 100 may support synchronous or asynchronous operation. For synchronous operation, the eNBs may have similar frame timing, and transmissions from different eNBs may be approximately aligned in time. For asynchronous operation, the eNBs may have different frame timing, and transmissions from different eNBs may not be aligned in time. In embodiments, some eNBs 105 may be synchronous while other eNBs may be asynchronous.

[0053] The communication devices 115 are dispersed throughout the wireless network 100, and each device may be stationary or mobile. A communication device 115 may also be referred to by those skilled in the art as a mobile station, a subscriber station, a mobile unit, a subscriber unit, a wireless unit, a remote unit, a mobile device, a wireless device, a wireless communications device, a remote device, a mobile subscriber station, an access terminal, a mobile terminal, a wireless terminal, a remote terminal, a handset, a user agent, a user equipment, a mobile client, a client, or some other suitable terminology. A communication device 115 may be a cellular phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a tablet computer, a laptop computer, a cordless phone, a wireless local loop (WLL) station, or the like. A communication device may be able to communicate with macro base stations, pico base stations, femto base stations, relay base stations, and the like.

[0054] The transmission links 125 shown in network 100 may include uplink (UL) transmissions from a mobile device 115 to a base station 105, and/or downlink (DL) transmissions, from a base station 105 to a mobile device 115. The downlink transmissions may also be called forward link transmissions while the uplink transmissions may also be called reverse link transmissions. In embodiments, the transmission links 125 are TDD carriers carrying bidirectional traffic within traffic frames.

[0055] In embodiments, the system 100 is an LTE/LTE-A network. In LTE/LTE-A networks, the terms evolved Node B (eNB) and user equipment (UE) may be generally used to describe the base stations 105 and communication devices 115, respectively. The system 100 may be a Heterogeneous LTE/LTE-A network in which different types of eNBs provide coverage for various geographical regions. For example, each eNB 105 may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cell. A macro cell generally covers a relatively large geographic area (*e.g.*, several kilometers in radius) and may allow unrestricted access by UEs with service subscriptions with the network provider. A pico cell would generally cover a relatively smaller geographic area and may allow unrestricted access by UEs with service subscriptions with the network provider. A femto cell would also generally cover a relatively small geographic area (*e.g.*, a home) and, in addition to unrestricted access, may also provide restricted access by UEs having an association with the femto cell (*e.g.*, UEs in a closed subscriber group (CSG), UEs for users in the home, and the like). An eNB for a macro cell may be referred to as a macro eNB. An eNB for a pico cell may be referred to as a pico eNB. And, an eNB for a femto cell may be referred to as a femto eNB or a home eNB. An eNB may support one or multiple (*e.g.*, two, three, four, and the like) cells.

[0056] The communications system 100 according to an LTE/LTE-A network architecture may be referred to as an Evolved Packet System (EPS) 100. The EPS 100 may include one or more UEs 115, an Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), an Evolved Packet Core (EPC) 130 (*e.g.*, core network 130), a Home Subscriber Server (HSS), and an Operator's IP Services. The EPS may interconnect with other access networks using other Radio Access Technologies. For example, EPS 100 may interconnect with a UTRAN-based network and/or a CDMA-based network via one or more Serving GPRS Support Nodes (SGSNs). To support mobility of UEs 115 and/or load balancing, EPS 100 may support handover of UEs 115 between a source eNB 105 and a target eNB 105. EPS 100 may support intra-RAT handover between eNBs 105 and/or base stations of the same RAT (*e.g.*, other E-UTRAN networks), and inter-RAT handovers between eNBs and/or base stations of different RATs (*e.g.*, E-UTRAN to CDMA, etc.). The EPS 100 may provide packet-switched services, however, as those skilled in the art will readily appreciate, the various concepts presented throughout this disclosure may be extended to networks providing circuit-switched services.

[0057] The E-UTRAN may include the eNBs 105 and may provide user plane and control plane protocol terminations toward the UEs 115. The eNBs 105 may be connected to other eNBs 105 via backhaul link 134 (*e.g.*, an X2 interface, and the like). The eNBs 105 may provide an access point to the EPC 130 for the UEs 115. The eNBs 105 may be connected by backhaul link 132 (*e.g.*, an S1 interface, and the like) to the EPC 130. Logical nodes within EPC 130 may include one or more Mobility Management Entities (MMEs), one or more Serving Gateways, and one or more Packet Data Network (PDN) Gateways (not shown). Generally, the MME may provide bearer and connection management. All user IP packets may be transferred through the Serving Gateway, which itself may be connected to the PDN Gateway. The PDN Gateway may provide UE IP address allocation as well as other functions. The PDN Gateway may be connected to IP networks and/or the operator's IP Services. These logical nodes may be implemented in separate physical nodes or one or more may be combined in a single physical node. The IP Networks/Operator's IP Services may include the Internet, an Intranet, an IP Multimedia Subsystem (IMS), and/or a Packet-Switched (PS) Streaming Service (PSS).

[0058] The UEs 115 may be configured to collaboratively communicate with multiple eNBs 105 through, for example, Multiple Input Multiple Output (MIMO), Coordinated Multi-Point (CoMP), or other schemes. MIMO techniques use multiple antennas on the base stations and/or multiple antennas on the UE to take advantage of multipath environments to transmit multiple data streams. Each data stream may be called a "layer" and the "rank" of the communication link may indicate the number of layers used for communication. CoMP includes techniques for dynamic coordination of transmission and reception by a number of eNBs to improve overall transmission quality for UEs as well as increasing network and spectrum utilization. Generally, CoMP techniques utilize backhaul links 132 and/or 134 for communication between base stations 105 to coordinate control plane and user plane communications for the UEs 115.

[0059] The communication networks that may accommodate some of the various disclosed embodiments may be packet-based networks that operate according to a layered protocol stack. In the user plane, communications at the bearer or Packet Data Convergence Protocol (PDCP) layer may be IP-based. A Radio Link Control (RLC) layer may perform packet segmentation and reassembly to communicate over logical channels. A Medium Access Control (MAC) layer may perform priority handling and multiplexing of logical channels into transport channels. The MAC layer may also use Hybrid ARQ (HARQ) to provide retransmission at the MAC layer to ensure reliable data transmission. In the control plane, the Radio Resource Control (RRC) protocol layer may provide establishment, configuration, and maintenance of an RRC connection between the UE and the network used for the user plane data. At the Physical layer, the transport channels may be mapped to Physical channels.

[0060] The downlink physical channels may include at least one of a physical downlink control channel (PDCCH), a physical hybrid ARQ indicator channel (PHICH), and a physical downlink shared channel (PDSCH). The uplink physical channels may include at least one of a physical uplink control channel (PUCCH) and a physical uplink shared channel (PUSCH). The UE may transmit control information in the PUCCH on the assigned resource blocks in the control section. The UE may transmit only data or both data and control information in the PUSCH on the assigned resource blocks in the data section. A UL transmission may span both slots of a subframe and may hop across frequency

[0061] LTE/LTE-A utilizes orthogonal frequency division multiple-access (OFDMA) on the downlink and single-carrier frequency division multiple-access (SC-FDMA) on the uplink. An OFDMA and/or SC-FDMA carrier may be partitioned into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, or the like. Each subcarrier may be modulated with data. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, K may be equal to 72, 180, 300, 600, 900, or 1200 with a subcarrier spacing of 15 kilohertz (KHz) for a corresponding system bandwidth (with guardband) of 1.4, 3, 5, 10, 15, or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into sub-bands. For example, a sub-band may cover 1.08 MHz, and there may be 1, 2, 4, 8 or 16 sub-bands.

[0062] The carriers may transmit bidirectional communications using FDD (*e.g.*, using paired spectrum resources) or TDD operation (*e.g.*, using unpaired spectrum resources). Frame structures for FDD (*e.g.*, frame structure type 1) and TDD (*e.g.*, frame structure type 2) may be defined. Time intervals may be expressed in multiples of a basic time unit $T_s = 1/30720000$. Each frame structure may have a radio frame length $T_f = 307200 \cdot T_s = 10\ ms$ and may include two half-frames of length $153600 \cdot T_s = 5\ ms$ each. Each half-frame may include five subframes of length $30720 \cdot T_s = 1\ ms$.

[0063] For TDD frame structures, each subframe may carry UL or DL traffic, and special subframes ("S") may be used to switch between DL to UL transmission. Allocation of UL and DL subframes within radio frames may be symmetric or asymmetric and may be reconfigured semi-statically (*e.g.*, via backhaul messaging over S1 and/or X2 interfaces, etc.). Special subframes may carry some DL and/or UL traffic and may include a Guard Period (GP) between DL and UL traffic. Switching from UL to DL traffic may be achieved by setting timing advance at the UEs without the use of Special subframes or a guard period between UL and DL subframes. UL-DL configurations with switch-point periodicity equal to the frame period (*e.g.*, 10 ms) or half of the frame period (*e.g.*, 5 ms) may be supported. For example, TDD frames may include one or more Special frames, and the period between Special frames may determine the TDD DL-to-UL switch-point periodicity for the frame.

[0064] For LTE/LTE-A, seven different UL-DL configurations are defined that provide between 40% and 90% DL subframes as illustrated in Table 1.

Table 1: TDD UL-DL Configurations

UL-DL Configuration	**Period (ms)**	**Subframe**									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	5	D	S	U	U	U	D	S	U	U	U
1	5	D	S	U	U	D	D	S	U	U	D
2	5	D	S	U	D	D	D	S	U	D	D
3	10	D	S	U	U	U	D	D	D	D	D
4	10	D	S	U	U	D	D	D	D	D	D
5	10	D	S	U	D	D	D	D	D	D	D
6	5	D	S	U	U	U	D	S	U	U	D

[0065] As indicated in Table 1, there are two switching periodicities, 5 ms and 10 ms. For configurations with 5 ms switching periodicities, there are two special subframes per frame, and for configurations with 10 ms switching periodicities there is one special subframe per frame. Some of these configurations are symmetric, having the same number of uplink and downlink slots, while some are asymmetric, having different numbers of uplink and downlink slots. For example, UL-DL configuration 1 is symmetric, with four uplink and four downlink subframes, UL-DL configuration 5 favors downlink throughput, and UL-DL configuration 0 favors uplink throughput.

[0066] In some aspects, rapidly changing traffic conditions may be accommodated through dynamic adaptation of UL-DL configuration for a particular eNB 105 and/or UE 115. Such dynamic reconfiguration may be transmitted to a UE 115 through signaling from the eNB 105, such as through control channel signaling, and apply to one or more subsequent TDD frames. Such reconfigurations may be accomplished according to “enhanced Interference Management and Traffic Adaptation” (eIMTA), which may be implemented in some networks.

[0067] While adaptive UL-DL configuration may increase the efficiency of TDD operation, it may cause DL-UL interference when adjacent eNBs have different TDD UL-DL configurations. **FIG. 2** illustrates an example network environment 200 using TDD carriers during a subframe where some TDD transmissions are UL and some are DL transmissions. Network environment 200 may illustrate, for example, aspects of wireless communications system 100 of FIG. 1. The subframe illustrated in FIG. 2 may be an UL subframe for eNB 105-a, a DL subframe for eNB 105-b, and an UL subframe for eNB 105-c. In the illustrated subframe, UE 115-a is performing an UL transmission 220-a to eNB 105-a, eNB 105-b is performing a DL transmission 230-b to UE 115-b, and UE 115-c is performing an UL transmission 220-c to eNB 105-c. Interfering DL transmission 235-b from eNB 105-b may cause DL-UL interference to UL transmission 220-a from UE 115-a and/or UL transmission 220-c from UE 115-c, while interfering UL transmissions 225-a and 225-c may cause UL-DL interference to UE 115-b. Because eNBs 105 generally transmit at a higher power level than UEs 115, the DL-UL interference may be greater than interference caused by other UEs (e.g., UL-DL and/or UL-UL interference).

[0068] LTE/LTE-A TDD operation supports multi-process Type II HARQ with a configurable number of independent HARQ processes. LTE/LTE-A uses asynchronous HARQ transmission on the downlink and synchronous HARQ transmission on the uplink. Adaptive modulation and coding (AMC) attempts to match the transmissions from a HARQ process to the channel conditions. For synchronous HARQ on the uplink, retransmission is assigned the same MCS and coding rate as the initial transmission.

[0069] The timing for the transmission of HARQ information in a TDD system is determined according to the particular TDD UL-DL configuration. For example, **FIG. 3** is a timing diagram 300 illustrating DL HARQ operation for two frames 310 in a TDD system. In the first frame 310-a and second frame 310-b, a serving cell is configured according to TDD UL-DL configuration 0 and an interfering cell is configured according to TDD UL-DL configuration 1. The HARQ process includes determining a HARQ ACK/NACK for each subframe and a resource index for transmission of the HARQ ACK/NACK. Upon receiving of a DL data transmission in a subframe *n*, the UE may determine a subframe for transmitting the associated ACK/NACK information according to *n*+*k*, where *k* is given in Table 2.

Table 2: Uplink ACK/NACK timing index k for TDD

UL-DL Configuration	**Subframe index n**									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	4	6	-	-	-	4	6	-	-	-
1	7	6	-	-	4	7	6	-	-	4
2	7	6	-	4	8	7	6	-	4	8
3	4	11	-	-	-	7	6	6	5	5
4	12	11	-	-	8	7	7	6	5	4
5	11	11	-	9	8	7	6	5	4	13
6	7	7	-	-	-	7	7	-	-	5

[0070] For DL HARQ process 0 illustrated in diagram 300, DL data may be transmitted from the serving cell to a UE during subframe 1 of frame 310-a. The UE may respond with ACK/NACK information 325-a for the DL transmission 320-a during subframe 7 of frame 310-a. In the illustrated example, subframe 7 of frame 310-a is also an UL subframe for the interfering cell. Therefore, when the serving cell receives ACK/NACK 325-a in subframe 7 of frame 310-a, the serving cell will also receive UL-UL interference from other UEs transmitting to the interfering cell. However, DL HARQ process 1 may experience different interference conditions. In particular, the ACK/NACK 325-b transmitted by the UE during subframe 9 of frame 310-a may incur DL-UL interference at the serving cell because of the DL transmission by the interfering cell. The relatively higher DL-UL interference during UL subframes of the serving cell corresponding to DL subframes of the interfering cell may result in degraded UL-DL scheduling performance, and a reduction in DL HARQ operation performance.

[0071] Interference from other cells may also have an impact on UL HARQ processes. Using synchronous UL HARQ operation, UL transmission and retransmission may occur on sub-frames with different interference characteristics (e.g., UL-UL and DL-UL), which may cause various inefficiencies in the UL HARQ processes. For example, if an UL transmission occurs on a subframe with UL-UL interference but retransmission occurs on a subframe with DL-UL interference, the retransmission will likely be difficult to decode at the serving cell. In contrast, where transmission occurs on a subframe with DL-UL interference and retransmission occurs on a subframe with UL-UL interference, rate selection for transmission may be too conservative.

[0072] **FIG. 4** is a timing diagram 400 illustrating UL HARQ operation for two frames 410-a and 410-b. In the first frame 410-a and second frame 410-b, a serving cell is configured according to TDD UL-DL configuration 0 and an interfering cell is configured according to TDD UL-DL configuration 1. In UL HARQ operation, ACK/NACK information for UL transmissions in a subframe *n* may be received in a subframe *n*+*k*, where *k* is given in Table 3.

Table 3: Downlink ACK/NACK timing index k for TDD

UL-DL Configuration	**Subframe index n**									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	-	-	4	7	6	-	-	4	7	6
1	-	-	4	6	-	-	-	4	6	-
2	-	-	6	-	-	-	-	6	-	-
3	-	-	6	6	6	-	-	-	-	-
4	-	-	6	6	-	-	-	-	-	-
5	-	-	6	-	-	-	-	-	-	-
6	-	-	4	6	6	-	-	4	7	-

[0073] In synchronous UL HARQ, each HARQ process will automatically (e.g., no explicit grant is required) retransmit in the next subframe available for transmission (e.g., with no scheduled UL transmission) at least 4 subframes after receiving the NACK for the original

UL transmission. As illustrated in timing diagram 400, HARQ process 0 may transmit UL data during subframe 2 of frame 410-a. ACK/NACK information 435-a for the data transmission may be received in subframe 6 of frame 410-a. Where ACK/NACK information 435-a indicates a NACK of the data transmission, the retransmission may occur in an UL subframe at least 4 subframes after ACK/NACK information 435-a is received (e.g., after subframe 0 of frame 410-b). Because HARQ process 6 may be scheduled in subframe 2 of frame 410-b, HARQ process 0 may perform retransmission 440-a in subframe 3 of frame 410-b. Retransmission 440-a occurs on an UL subframe of the serving cell that corresponds to a DL subframe of the interfering cell. Because the noise power spectral density at the serving cell is likely higher during the retransmission, it may be difficult for the serving cell to decode retransmission 440-a correctly. Thus, the UL HARQ process may require additional retransmissions and efficiency may be lost.

[0074] Similarly, HARQ process 2 experiences different interference profiles on transmission and retransmission. Transmission 430-b occurs during subframe 4 of frame 410-a, which for the interfering cell is a DL subframe. Retransmission 440-b after receiving NACK 435-b occurs on subframe 7 of frame 410-b, which for the interfering cell is an UL subframe. Thus, retransmission 440-b will likely experience lower noise power spectral density at the serving cell and transmission rate selection for HARQ process 2 may be too conservative, causing a lower than necessary data rate to be used.

[0075] In embodiments, the different aspects of system 100 and/or environment 200, such as the eNBs 105 and UEs 115, may be configured to mitigate the effects of downlink-to-uplink interference in TDD systems by adapting timing for uplink control information and UL HARQ retransmission. In some embodiments, uplink control information may be shifted to subframes that experience lower downlink interference from other cells. In instances where TDD UL-DL configurations for neighboring cells are known, subframes for transmission of uplink control information may be selected based on common UL subframes between the TDD UL-DL configurations used for the serving cell and the neighboring cells. In instances where TDD UL-DL configurations for neighboring cells are unknown, subframes for transmission of uplink control information may be selected based on UL subframes common to available TDD UL-DL configurations. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UCI transmission performance with UL/DL flexibility.

[0076] In some embodiments UL HARQ timing is modified such that UL transmissions and retransmissions experience similar interference profiles. In embodiments, asynchronized UL HARQ may be used to schedule retransmissions in UL subframes with similar interference profiles as the original transmission (e.g., either UL-UL interference or DL-UL interference, etc.). In other embodiments, modified synchronous UL HARQ timing adapts retransmission to occur on UL subframes with similar interference profiles as the transmission based on the TDD UL-DL configuration of the serving cell. Where TDD UL-DL configurations for neighboring cells are known, the new UL HARQ timing may be based on the known TDD UL-DL configurations. Where TDD UL-DL configurations for neighboring cells are unknown, the new UL HARQ timing may select UL subframes for retransmissions experiencing similar interference profiles as the original transmission for all available TDD UL-DL configurations of the neighboring cells. The set of available UL-DL configurations for neighboring cells may be adapted to trade off UL HARQ performance with UL/DL flexibility.

[0077] **FIG. 5A** is a timing diagram 500-a showing shifted UCI timing using known interfering cell TDD UL-DL configurations in accordance with various embodiments. In timing diagram 500-a, a TDD carrier of a serving cell is configured according to TDD UL-DL configuration 0 and a TDD carrier of an interfering cell is configured according to TDD UL-DL configuration 1 for a first frame 510-a and second frame 510-b. Shifted UCI timing as illustrated in FIG. 5A may be employed in TDD network environments such as systems 100 and/or 200.

[0078] In timing diagram 500-a, DL transmission 520-a from the serving cell for HARQ process 1 occurs on subframe 5 of frame 510-a. According to timing diagram 500-a, the receiving UE shifts transmission of DL HARQ ACK/NACK 525-a from subframe 9 of frame 510-a, which experiences DL-UL interference from the interfering cell, to subframe 2 of frame 510-b, which experiences UL-UL interference. Similarly, HARQ process 3 may receive DL transmission 525-b on subframe 0 of frame 510-b and shift the DL HARQ ACK/NACK 525-b from subframe 4 of frame 510-b to subframe 7 of frame 510-b. While FIG. 5A illustrates one example of shifted UCI timing where the serving cell uses TDD UL-DL configuration 0 and the interfering cell uses TDD UL-DL configuration 1, one of skill in the art may apply the illustrated techniques to any combination of TDD UL-DL configurations as well as instances where there are multiple interfering cells.

[0079] **FIG. 5B** is a timing diagram 500-b illustrating an alternative embodiment for UCI shifting where TDD UL-DL configurations for neighboring or potentially interfering cells are not known by the serving cell and/or UE. As illustrated in timing diagram 500-b, the set of TDD UL-DL configurations for the serving and neighboring cells may have some subframes that are always UL or DL subframes. As illustrated in timing diagram 500-b, subframe 2 is an UL subframe for LTE/LTE-A TDD UL-DL configurations 0 through 6. In timing diagram 500-b, the UE shifts UCI transmissions to subframe 2. For example, the UE may receive DL transmission 520-c during subframe 1 of frame 510-c and shift DL HARQ ACK/NACK 525-c for DL transmission 520-c from subframe 7 of frame 510-c to subframe. The UE may also shift DL HARQ ACK/NACKs 525-d and 525-e to subframe 2 of frames 510-c or 510-d.

[0080] In some configurations consistent with FIGS. 5A and/or 5B, a UE may convert multiple HARQ ACK/NACKs into a single HARQ ACK/NACK via bundling or multiplexing. Bundling of acknowledgments includes combining the outcome of the determined ACK/NACK from multiple subframes into a single HARQ acknowledgment. Such combining may be accomplished through, for example, a logical AND of the respective ACK/NACK determinations. In some aspects, the single HARQ acknowledgement is transmitted from one of the determined HARQ resource index.

[0081] While timing diagrams 500-a and 500-b illustrate shifting DL HARQ ACK/NACK information, other uplink control information (UCI) for transmission to the serving cell may also be shifted to subframes experiencing UL-UL interference. Shifted UCI may include sounding reference signals (SRS), channel state information (CSI), channel quality information (CQI), rank indicator (RI), precoding matrix indicator (PMI), and scheduling requests (SR), according to various embodiments.

[0082] **FIG. 6A** illustrates a method 600-a for shifting UCI at a UE to mitigate DL-UL interference in accordance with various embodiments. Method 600-a may be used in environment 200 and/or system 100. Method 600-a may be used, for example, by UEs 115 illustrated in FIG. 1 and/or FIG. 2 for shifting UCI from subframes with DL-UL interference to UL-UL interference subframes.

[0083] Method 600-a may begin at block 605 where UCI is determined for transmission to a serving cell. For example, SRS, CSI, CQI, RI, PMI, SR, and/or DL HARQ ACK/NACK information may be determined by the UE for transmission and may be scheduled for transmission during subframes determined according to various UCI transmission schedules.

[0084] At block 610, the UE 115 may determine TDD UL/DL configurations for one or more adjacent and/or interfering cells. For example, UE 115 may receive the TDD UL/DL configurations for neighboring cells from the serving cell. At block 615, the UE may determine reduced interference UL subframes based on TDD UL/DL configurations of the serving cell and one or more interfering cells. For example, the UE may determine common UL subframes between the serving cell TDD UL/DL configuration and the TDD UL/DL configurations of potentially interfering cells.

[0085] At block 620, the may select a reduced interference UL subframe for transmission of the UCI from the UE to the serving cell. At block 625, the UE may transmit the UCI on the selected reduced interference UL subframe to the serving cell.

[0086] **FIG. 6B** illustrates a method 600-b for shifting UCI at a serving cell to mitigate DL-UL interference in accordance with various embodiments. Method 600-b may be used in environment 200 and/or system 100. Method 600-b may be used, for example, by eNBs 105 illustrated in FIG. 1 and/or FIG. 2 for shifting UCI from subframes with DL-UL interference to UL-UL interference subframes.

[0087] Method 600-b may begin at block 630 where the serving cell may transmit DL data to a UE. At block 635, the serving cell may determine TDD UL/DL configurations for one or more adjacent and/or interfering cells. For example, the serving cell may receive (e.g., via backhaul) the TDD UL/DL configurations for neighboring cells. The serving cell may send the TDD UL/DL configurations for neighboring cells to the UE. Alternatively, the serving cell may determine the TDD UL/DL configurations for potentially interfering cells by detecting the TDD UL/DL configurations from transmitted signals from the potentially interfering cells (e.g., detecting reference signals, etc.).

[0088] At block 640, the serving cell may determine reduced interference UL subframes based on TDD UL/DL configurations of the serving cell and one or more interfering cells. For example, the UE and/or serving cell may determine common UL subframes between the serving cell TDD UL/DL configuration and the TDD UL/DL configurations of potentially interfering cells.

[0089] At block 645, the serving cell may select a reduced interference UL subframe for transmission of the UCI from the UE to the serving cell. At block 650, the UE may decode the UCI received on the selected reduced interference UL subframe.

[0090] **FIG. 7A** illustrates an alternative method 700-a for shifting UCI at a UE to mitigate DL-UL interference of a TDD carrier when UL-DL configurations for potentially interfering cells are unknown. Method 700-a may be used in environment 200 and/or system 100. Method 700-a may be used, for example, by UEs 115 illustrated in FIG. 1 and/or FIG. 2 for shifting UCI from subframes with DL-UL interference to UL-UL interference subframes.

[0091] Method 700-a may begin at block 705 where UCI is determined for transmission to a serving cell. For example, SRS, CSI, CQI, RI, PMI, SR, and/or DL HARQ ACK/NACK information may be determined by the UE for transmission and may be scheduled for transmission during subframes determined according to various UCI transmission schedules.

[0092] At block 710, the UE may determine reduced interference UL subframes for transmission of the UCI based on the TDD UL/DL configuration of the serving cell and available TDD UL-DL configurations for one or more potentially interfering cells. For example, the UE may determine, based on the set of available TDD UL/DL configurations, one or more subframes that are UL subframes in the set of configurations. In some embodiments, the set of UL/DL configurations may be selected for use by neighboring cells (e.g., cell clusters, etc.) to improve UCI shifting performance at the expense of TDD UL-DL configuration flexibility. The selected set of UL-DL configurations may be a subset of TDD UL-DL configurations. In one example, the selected set of TDD UL-DL configurations includes configurations with a TDD switch period of 5 ms (e.g., TDD UL-DL configurations 0, 1, 2, and 6). These TDD UL-DL configurations have two UL subframes in common and may improve performance for UCI shifting at the expense of some DL capacity.

[0093] At block 715, the UE may select a reduced interference UL subframe for transmission of the UCI from the UE to the serving cell. At block 720, the UE may transmit the UCI on the selected reduced interference UL subframe to the serving cell.

[0094] **FIG. 7B** illustrates an alternative method 700-b for shifting UCI at a serving cell to mitigate DL-UL interference of a TDD carrier when UL-DL configurations for potentially interfering cells are unknown. Method 700-b may be used in environment 200 and/or system 100. Method 700-b may be used, for example, by eNBs 105 illustrated in FIG. 1 and/or FIG.

2 for shifting UCI from subframes with DL-UL interference to UL-UL interference subframes.

[0095] Method 700-b may begin at block 730 where the serving cell may transmit DL data to a UE. At block 735, the serving cell may determine reduced interference UL subframes for receiving UCI associated with the DL transmissions based on the TDD UL/DL configuration of the serving cell and available TDD UL-DL configurations for one or more potentially interfering cells. For example, the serving cell may determine, based on the set of available TDD UL/DL configurations, one or more subframes that are UL subframes across the set of configurations. In some embodiments, the set of UL/DL configurations may be selected for use by neighboring cells (e.g., cell clusters, etc.) to improve UCI shifting performance at the expense of TDD UL-DL configuration flexibility. The selected set of UL-DL configurations may be a subset of TDD UL-DL configurations. In one example, the selected set of TDD UL-DL configurations includes configurations with a TDD switch period of 5 ms (e.g., TDD UL-DL configurations 0, 1, 2, and 6). These TDD UL-DL configurations have two UL subframes in common and may improve performance for UCI shifting at the expense of some DL capacity.

[0096] At block 740, the serving cell may select a reduced interference UL subframe for receiving UCI from the UE. At block 745, the serving cell may decode the UCI received on the selected UL subframe.

[0097] **FIG. 8A** is a timing diagram 800-a illustrating modified synchronous UL HARQ timing in accordance with various embodiments. In timing diagram 800-a, a TDD carrier of a serving cell is configured according to TDD UL-DL configuration 0 and a TDD carrier of an interfering cell is configured according to TDD UL-DL configuration 1 for frames 810-a through 810-d. Modified synchronous UL HARQ timing as illustrated in FIG. 8A may be employed in TDD network environments such as systems 100 and/or 200.

[0098] As illustrated in timing diagram 800-a, HARQ process 1 may perform an UL data transmission during subframe 3 of frame 810-a. ACK/NACK information 835-a for the data transmission may be received in subframe 0 of frame 810-b. Where ACK/NACK information 835-a indicates a NACK of the UL data transmission, the retransmission 840-a may occur in an UL subframe at least 4 subframes after ACK/NACK information 835-a is received (e.g., on or after subframe 4 of frame 810-b). While subframe 4 of frame 810-b may be available for UL transmission, the UE may perform the retransmission 840-a on subframe 8 of frame 810-b according to the modified synchronous UL HARQ timing illustrated in timing diagram 800-a.

[0099] **FIG. 8B** is a timing diagram 800-b illustrating another example of modified synchronous UL HARQ timing in accordance with various embodiments. In timing diagram 800-b, a TDD carrier of a serving cell is configured according to TDD UL-DL configuration 6 and a TDD carrier of an interfering cell is configured according to TDD UL-DL configuration 3 for frames 810-e through 810-h. Modified synchronous UL HARQ timing as illustrated in FIG. 8B may be employed in TDD network environments such as systems 100 and/or 200.

[0100] As illustrated in timing diagram 800-b, HARQ process 4 may perform an UL data transmission during subframe 8 of frame 810-e. ACK/NACK information 835-b for the data transmission may be received in subframe 5 of frame 810-f. Where ACK/NACK information 835-b indicates a NACK of the UL data transmission, the retransmission 840-b may occur in an UL subframe at least 4 subframes after ACK/NACK information 835-b is received (e.g., on or after subframe 9 of frame 810-f). While subframe 2 of frame 810-g may be available for UL transmission, the UE may perform the retransmission 840-b on subframe 8 of frame 810-g according to the modified synchronous UL HARQ timing illustrated in timing diagram 800-b.

[0101] According to the architecture of FIGS. 8A and 8B, the modified synchronous UL HARQ timing may perform UL retransmissions for each UL HARQ process on a next available UL subframe (e.g., on or after 4 subframes after receiving the NACK) with an interference profile (e.g., DL-UL interference or UL-UL interference) matching the original transmission. Thus, while FIGS. 8A and 8B illustrate examples of modified synchronous UL HARQ timing for specific TDD UL-DL configurations for the serving cell and interfering cell, one of skill in the art may apply the illustrated techniques to any combination of TDD UL-DL configurations as well as instances where there are multiple interfering cells.

[0102] In some embodiments, the set of UL/DL configurations may be selected for use by neighboring cells (e.g., cell clusters, etc.) to improve synchronous UL HARQ performance at the expense of TDD UL-DL configuration flexibility. The selected set of UL-DL configurations may be a subset of TDD UL-DL configurations. In one example, the selected set of TDD UL-DL configurations includes configurations with a TDD switch period of 5 ms (e.g., configurations 0, 1, 2, and 6). These TDD UL-DL configurations have two UL subframes in common and may improve performance for the modified synchronous UL HARQ techniques described with reference to FIGS. 8A and 8B at the expense of some DL capacity.

[0103] **FIG. 8C** is a timing diagram 800-c illustrating an alternative embodiment of modified synchronous UL HARQ timing where TDD UL-DL configurations for interfering cells are unknown. In timing diagram 800-c, a TDD carrier of a serving cell is configured according to TDD UL-DL configuration 0 and the TDD UL-DL configuration for a TDD carrier of an interfering cell is unknown for frames 810-i through 810-l. Modified synchronous UL HARQ timing as illustrated in FIG. 8C may be employed in TDD network environments such as systems 100 and/or 200.

[0104] As illustrated in timing diagram 800-c, UL HARQ processes may perform UL data retransmissions during UL subframes with the same subframe number as the original UL transmissions. For example, UL HARQ process 1 may send UL data transmission 830-c during subframe 3 of frame 810-i and receive ACK/NACK information 835-c for the data in subframe 0 of frame 810-j. Where ACK/NACK information 835-c indicates a NACK of the UL data transmission, the retransmission 840-c may occur in an UL subframe at least 4 subframes after ACK/NACK information 835-c is received (e.g., on or after subframe 4 of frame 810-j). While subframe 4 of frame 810-j may be available for UL transmission, the UE may perform the retransmission 840-c on subframe 3 of frame 810-k according to the modified synchronous UL HARQ timing illustrated in timing diagram 800-c.

[0105] **FIG. 9A** illustrates a method 900-a for performing modified synchronous UL HARQ timing in accordance with various embodiments. Method 900-a may be used in environment 200 and/or system 100. Method 900-a may be used, for example, UEs 115 illustrated in FIG. 1 and/or FIG. 2 for performing UL HARQ retransmissions during subframes with the same interference profile (e.g., DL-UL interference or UL-UL interference) as the original transmission. Method 900-a may be performed by each UL HARQ process of the UEs 115.

[0106] Method 900-a may begin at block 905, where an UL HARQ process at the UE may perform a data transmission during an UL subframe. At block 910, the UE may receive a

NACK from the serving cell for the UL transmission. At block 915, the UE may determine TDD UL-DL configurations of possibly interfering cells. For example, the serving cell may transmit the TDD UL-DL configurations for possibly interfering cells to the UE. At block 920, the UE may select an UL subframe for retransmission having the same interference profile as the UL subframe of the original data transmission in block 905. The UE may also determine the UL subframe for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after receiving NACK, etc.).

[0107] At block 925, the UE may determine whether there is a scheduled data transmission on the selected UL subframe from block 920. If a data transmission is already scheduled on the selected subframe, method 900-a may return to block 915 to select a new UL subframe for retransmission based on the TDD UL-DL configurations of interfering cells.

[0108] If there is no scheduled transmission on the selected UL subframe at block 925, the UE may perform the retransmission on the selected UL subframe at block 930. The UL HARQ process may be repeated if another NACK is received for the retransmission at block 930.

[0109] **FIG. 9B** illustrates a method 900-b for performing modified synchronous UL HARQ timing in accordance with various embodiments. Method 900-b may be used in environment 200 and/or system 100. Method 900-b may be used, for example, by eNBs 105 illustrated in FIG. 1 and/or FIG. 2 for performing UL HARQ retransmissions during subframes with the same interference profile (e.g., DL-UL interference or UL-UL interference) as the original transmission. Method 900-b may be performed by each UL HARQ process of the eNBs 105.

[0110] Method 900-b may begin at block 935, where an UL HARQ process at the serving cell may receive an UL data transmission during an UL subframe. The serving cell may not be able to correctly decode the UL data transmission and may transmit a NACK to the UE for the data transmission at block 940. At block 945, the serving cell may determine TDD UL-DL configurations of possibly interfering cells. For example, the serving cell may receive TDD UL-DL configurations from neighboring cells or may detect TDD UL-DL configurations of neighboring cells. At block 950, the serving cell may select an UL subframe for receiving a retransmission having the same interference profile as the UL subframe of the original data transmission in block 935. The serving cell may also determine the UL subframe for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after transmitting NACK, etc.).

[0111] At block 955, the serving cell may determine whether there is a scheduled data transmission on the selected UL subframe from block 950. If a data transmission is already scheduled on the selected subframe, method 900-b may return to block 945 to select a new UL subframe for receiving the retransmission based on the TDD UL-DL configurations of interfering cells.

[0112] If there is no scheduled transmission on the selected UL subframe at block 955, the serving cell may receive the retransmission on the selected UL subframe at block 960. The UL HARQ process may be repeated from block 940 if the data being transmitted in the UL HARQ process is still not able to be decoded correctly at block 960.

[0113] FIGS. 8A, 8B, 8C, 9A, and 9B illustrate techniques for modifying synchronous UL HARQ timing. However, the principles of these techniques may be applied to asynchronous UL HARQ as well. For example, the serving cell may follow the timing illustrated above with reference to FIGS. 8A, 8B, and/or 8C in scheduling UL retransmissions for asynchronous UL HARQ.

[0114] **FIG. 10** illustrates a system 1000 for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments. System 1000 includes an eNB 105-h and UE 115-d. The eNB 105-h may be an example of the eNBs 105 illustrated in FIG. 1 and/or FIG. 2. The UE 115-d may be an example of the UEs 115 illustrated in FIG. 1 and/or FIG. 2. For simplicity, eNB 105-h and UE 115-d are each illustrated with a single antenna, however, they may have multiple antennas

[0115] The eNB 105-h may include TDD configuration processor 1005, DL HARQ/UCI processor 1010, UL HARQ processor, modulator/demodulator 1020, memory 1030, scheduler 1035, transmitter/receiver 1040 and antenna(s) 1042. Each of these components may be connected to each other.

[0116] DL HARQ/UCI processor 1010 may, in coordination with scheduler 1035 and TDD configuration processor 1005, schedule DL transmissions and receive UCI associated with DL data transmissions. For example, DL HARQ/UCI processor 1010 may receive ACK/NACK information related to the DL data transmissions and other UCI such as SRS, CSI, CQI, RI, PMI and/or SR. DL HARQ/UCI processor 1010 may determine TDD UL/DL configurations for one or more adjacent and/or interfering cells. For example, DL HARQ/UCI processor 1010 may receive (e.g., via backhaul) the TDD UL/DL configurations for neighboring cells and/or detect the TDD UL/DL configurations of neighboring cells from transmitted signals (e.g., detecting reference signals, etc.). DL HARQ/UCI processor 1010 may determine reduced interference UL subframes based on TDD UL/DL configurations of the eNB 105-h and one or more interfering cells. For example, DL HARQ/UCI processor 1010 may determine common UL subframes between the serving cell TDD UL/DL configuration and the TDD UL/DL configurations of potentially interfering cells. DL HARQ/UCI processor 1010 may receive the UCI in the reduced interference UL subframes.

[0117] UL HARQ processor 1015 may perform the operations for one or more UL HARQ processes. UL HARQ processor 1015 may receive UL data transmissions from modulator/demodulator 1020 and decode the UL data transmissions. When UL data transmissions associated with one or more UL HARQ processes are not decoded correctly, UL HARQ processor 1015 may transmit a NACK to the UE for the incorrectly decoded data transmissions. UL HARQ processor 1015 may determine TDD UL-DL configurations of possibly interfering cells. For example, the UL HARQ processor 1015 may receive TDD UL-DL configurations from neighboring cells or may detect TDD UL-DL configurations of neighboring cells. UL HARQ processor 1015 may select UL subframes for receiving retransmissions having the same interference profiles as the UL subframes of the original data transmissions. UL HARQ processor 1015 may also determine the UL subframe for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after transmitting NACK, priority of scheduled UL transmissions, etc.).

[0118] The UE 115-d may include DL HARQ/UCI processor 1055, UL HARQ processor 1060, modulator/demodulator 1050, memory 1070, transmitter/receiver 1045, and antenna(s) 1044. Each of these components may be connected to each other.

[0119] DL HARQ/UCI processor 1055 may determine UCI for transmission to a serving cell. For example, SRS, CSI, CQI, RI, PMI, SR, and/or DL HARQ ACK/NACK information may be determined by the UE for transmission and may be scheduled for transmission during subframes determined according to various UCI transmission schedules. DL HARQ/UCI processor 1055 may determine TDD UL/DL configurations for one or more adjacent and/or interfering cells. DL HARQ/UCI processor 1055 may determine reduced interference UL subframes for transmission of the UCI. In some embodiments, DL HARQ/UCI processor 1055 may determine the reduced interference UL subframes based on TDD UL/DL configurations of the serving cell and one or more interfering cells. Alternatively, DL HARQ/UCI processor 1055 may determine the reduced interference UL subframes based on one or more subframes that are UL subframes of a set of available TDD UL/DL configurations. DL HARQ/UCI processor 1055 may select a reduced interference UL subframe for transmission of the UCI and transmit the UCI on the selected reduced interference UL subframe to the eNB 105-h.

[0120] UL HARQ processor 1060 may perform multi-process synchronous UL HARQ according to the modified synchronous UL HARQ timing described above. For example, UL HARQ processor 1060 may perform data transmissions during UL subframes and receive ACK/NACK information from the serving cell (e.g., eNB 105-h). When NACKs are received for UL transmissions, UL HARQ processor 1060 may select UL subframes for retransmission having the same interference profile as the UL subframe of the original data transmissions. Where the TDD UL-DL configurations for possibly interfering cells are known, the UL HARQ processor 1060 may select the UL subframes for retransmission based on the TDD UL-DL configurations for the possibly interfering cells. Where the TDD UL-DL configurations for possibly interfering cells are unknown, the UL HARQ processor 1060 may select the same numbered UL subframes for retransmission as the original transmissions. UL HARQ processor 1060 may also determine the UL subframes for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after receiving NACK, priority of scheduled UL transmissions, etc.). The UL HARQ processor 1060 may perform the retransmissions on the selected UL subframes.

[0121] Modulators/demodulators 1020, 1050 may process a respective output symbol stream (*e.g.*, for OFDM, SC-FMDA, etc.) to obtain an output sample stream. Each modulator/demodulator 1020, 1050 may further process (*e.g.*, convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink (DL) signal. In one example, DL signals from modulators/demodulators 1020, 1050 may be transmitted via the transmitter/receivers 1040, 1045 and antennas 1042, 1044, respectively, according to a particular TDD Uplink/Downlink configuration. Modulators/demodulators 1020, 1050 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal from transmitter/receivers 1040, 1045 and antennas 1042, 1044 to obtain input samples. Modulators/demodulators 1020, 1050 may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols.

[0122] **FIG. 11** shows a block diagram of a design of DL HARQ/UCI processor 1055 in accordance with various embodiments. DL HARQ/UCI processor 1055 may include uplink control information module 1110, reduced interference UL subframe module 1120, and/or UCI transmission module 1130. Each of these components may be in communication with each other.

[0123] Uplink control information module 1110 may determine UCI for transmission to a serving cell during UL subframes. Reduced interference UL subframe module 1120 may determine reduced interference UL subframes. Where TDD UL-DL configurations of possibly interfering cells are known, reduced interference UL subframe module 1120 may determine reduced interference UL subframes based on the TDD UL-DL configuration of the serving cell and the TDD UL-DL configurations of the possibly interfering cells. Where TDD UL-DL configurations of possibly interfering cells are unknown, reduced interference UL subframe module 1120 may determine reduced interference UL subframes based on the TDD UL-DL configuration of the serving cell and the set of available TDD UL-DL configurations for interfering cells. UCI transmission module 1130 may transmit the UCI on the reduced interference subframes.

[0124] **FIG. 12** shows a block diagram of a design of UL HARQ processor 1060 in accordance with various embodiments. UL HARQ processor 1060 may include ACK/NACK processing module 1210, UL retransmission subframe module 1220, and TDD configuration module 1230. Each of these components may be in communication with each other.

[0125] ACK/NACK processing module 1210 may receive and process ACK/NACK information in a multi-process UL HARQ operation. UL retransmission subframe module 1220 may select UL subframes for retransmission of data transmissions for which NACKs are received. UL retransmission subframe module 1220 may select UL subframes for retransmissions having the same interference profile as the UL subframes of the original data transmissions. In embodiments, TDD configuration module 1230 may determine TDD UL-DL configurations for possibly interfering cells. The UL retransmission subframe module 1220 may select the UL subframes for retransmission based on the TDD UL-DL configurations for the possibly interfering cells. Where the TDD UL-DL configurations for possibly interfering cells are unknown, the UL retransmission subframe module 1220 may select the same numbered UL subframes for retransmission as the original transmissions. UL retransmission subframe module 1220 may also determine the UL subframes for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after receiving NACK, priority of scheduled UL transmissions, etc.).

[0126] **FIG. 13** shows a block diagram of a design of DL HARQ/UCI processor 1010 of a serving cell in accordance with various embodiments. DL HARQ/UCI processor 1010 may include data transmission module 1310, reduced interference UL subframe module 1320, and UCI decoding module 1330. Each of these components may be in communication with each other.

[0127] Data transmission module 1310 may transmit DL data transmissions to UEs in DL subframes of TDD carriers. Reduced interference UL subframe module 1320 may determine reduced interference UL subframes for receiving UCI from the UEs associated with the DL data transmissions. Reduced interference UL subframe module 1320 may determine the reduced interference UL subframes based on TDD UL/DL configurations the serving cell and one or more interfering cells. In some embodiments, reduced interference UL subframe module 1320 may determine the reduced interference UL subframes based on TDD UL/DL configurations of the serving cell and one or more interfering cells. Alternatively, reduced interference UL subframe module 1320 may determine the reduced interference UL subframes based on one or more subframes that are UL subframes of a set of available TDD UL/DL configurations. UCI decoding module 1330 may decode the UCI received on the reduced interference UL subframes.

[0128] **FIG. 14** shows a block diagram of a design of UL HARQ processor 1015 of a serving cell in accordance with various embodiments. UL HARQ processor 1015 may include UL data processing module 1410, UL ACK/NACK transmission module 1420, and UL retransmission subframe module 1430. Each of these components may be in communication with each other.

[0129] UL data processing module 1410 may receive and process UL data transmissions from UEs in a multi-process UL HARQ operation. UL ACK/NACK transmission module 1420 may transmit ACK/NACK information for received UL subframes. For example, UL

ACK/NACK transmission module 1420 may transmit NACKs for UL subframes not decoded correctly by UL data processing module 1410. UL retransmission subframe module 1430 may select UL subframes for receiving retransmissions from UEs having the same interference profile as the UL subframes of the original data transmissions. In embodiments, UL retransmission subframe module 1430 may select the UL subframes for retransmission based on the TDD UL-DL configurations for the possibly interfering cells. Where the TDD UL-DL configurations for possibly interfering cells are unknown, the UL retransmission subframe module 1430 may select the same numbered UL subframes for retransmission as the original transmissions. UL retransmission subframe module 1430 may also determine the UL subframes for retransmission according to other synchronous UL HARQ rules (e.g., at least 4 subframes after receiving NACK, priority of scheduled UL transmissions, etc.). UL data processing module 1410 may receive the retransmitted UL subframes.

[0130] The components FIGS. 11, 12, 13 and/or 14 may, individually or collectively, be implemented with one or more application-specific integrated circuits (ASICs) adapted to perform some or all of the applicable functions in hardware. Alternatively, the functions may be performed by one or more other processing units (or cores), on one or more integrated circuits. In other embodiments, other types of integrated circuits may be used (*e.g.*, Structured/Platform ASICs, Field Programmable Gate Arrays (FPGAs), and other Semi-Custom ICs), which may be programmed in any manner known in the art. The functions of each unit may also be implemented, in whole or in part, with instructions embodied in a memory, formatted to be executed by one or more general or application-specific processors.

[0131] **FIG. 15** is a block diagram 1500 of a mobile device 115-e configured for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments. The mobile device 115-e may have any of various configurations, such as personal computers (*e.g.*, laptop computers, netbook computers, tablet computers, etc.), cellular telephones, PDAs, smartphones, digital video recorders (DVRs), internet appliances, gaming consoles, e-readers, etc. The mobile device 115-e may have an internal power supply (not shown), such as a small battery, to facilitate mobile operation. In some embodiments, the mobile device 115-e may be the mobile devices 115 of FIG. 1, FIG. 2, and/or FIG. 10.

[0132] The mobile device 115-e may generally include components for bi-directional voice and data communications including components for transmitting communications and components for receiving communications. The mobile device 115-e may include a transceiver module 1510, antenna(s) 1505, memory 1580, and a processor module 1570, which each may communicate, directly or indirectly, with each other (*e.g.*, via one or more buses). The transceiver module 1510 is configured to communicate bi-directionally, via the antenna(s) 1505 and/or one or more wired or wireless links, with one or more networks, as described above. For example, the transceiver module 1510 may be configured to communicate bi-directionally with base stations 105 of FIG. 1, FIG. 2, and/or FIG. 10. The transceiver module 1510 may include a modem configured to modulate the packets and provide the modulated packets to the antenna(s) 1505 for transmission, and to demodulate packets received from the antenna(s) 1505. While the mobile device 115-e may include a single antenna 1505, the mobile device 115-c may have multiple antennas 1505 capable of concurrently transmitting and/or receiving multiple wireless transmissions. The transceiver module 1510 may be capable of concurrently communicating with multiple eNBs 105 via multiple component carriers.

[0133] The memory 1580 may include random access memory (RAM) and read-only memory (ROM). The memory 1580 may store computer-readable, computer-executable software/firmware code 1585 containing instructions that are configured to, when executed, cause the processor module 1570 to perform various functions described herein (*e.g.*, call processing, database management, capture of handover delay, etc.). Alternatively, the software/firmware code 1585 may not be directly executable by the processor module 1570 but be configured to cause a computer (*e.g.*, when compiled and executed) to perform functions described herein.

[0134] The processor module 1570 may include an intelligent hardware device, *e.g.*, a central processing unit (CPU) such as those made by Intel® Corporation or AMD®, a microcontroller, an application-specific integrated circuit (ASIC), etc. The mobile device 115-e may include a speech encoder (not shown) configured to receive audio via a microphone, convert the audio into packets (*e.g.*, 20 ms in length, 30 ms in length, etc.) representative of the received audio, provide the audio packets to the transceiver module 1510, and provide indications of whether a user is speaking.

[0135] According to the architecture of FIG. 15, the mobile device 115-e may further include communications management module 1560, handover module 1565, uplink control information module 1110-a, reduced interference UL subframe module 1120-a, UCI transmission module 1130-a, ACK/NACK processing module 1210-a, UL retransmission subframe module 1220-a, and/or TDD configuration module 1230-a. By way of example, these modules may be components of the mobile device 115-e in communication with some or all of the other components of the mobile device 115-e via a bus. Alternatively, functionality of these modules may be implemented as a component of the transceiver module 1510, as a computer program product, and/or as one or more controller elements of the processor module 1570.

[0136] In some embodiments, handover module 1565 may be utilized to perform handover procedures of the mobile device 115-e from one base station 105 to another. For example, the handover module 1565 may perform a handover procedure of the mobile device 115-e from one base station to another where voice and/or data communications are being received from the base stations.

[0137] The mobile device 115-e may be configured to support UCI shifting and/or modifying of synchronous UL HARQ timing as described above. The components for mobile device 115-e may be configured to implement aspects discussed above with respect to UEs 115 of FIG. 1, FIG. 2, and/or FIG. 10 and may not be repeated here for the sake of brevity. For example, the uplink control information module 1110-a may be an example of one or more aspects of the uplink control information module 1110, reduced interference UL subframe module 1120-a may be an example of one or more aspects of the reduced interference UL subframe module 1120, UCI transmission module 1130-a may be an example of one or more aspects of the UCI transmission module 1130, ACK/NACK processing module 1210-a may be an example of one or more aspects of the ACK/NACK processing module 1210, UL retransmission subframe module 1220-a may be an example of one or more aspects of the UL retransmission subframe module 1220-a, and/or TDD configuration module 1230-a may be an example of one or more aspects of the TDD configuration module 1230.

[0138] **FIG. 16** shows a block diagram of a communications system 1600 that may be configured for performing UCI shift and/or modifying synchronous UL HARQ timing in accordance with various embodiments. This system 1600 may be an example of aspects of the systems 100 and/or 200 depicted in FIG. 1 and/or FIG. 2. The system 1600 includes a base station 105-i configured for communication with UE 115 over wireless communication links 125. Base station 105-i may be capable of receiving communication links 125 from other base stations such as base station 105-j. Base station 105-i may be, for example, an eNB 105 as illustrated in systems 100 and/or 200.

[0139] In some cases, the base station 105-i may have one or more wired backhaul links. Base station 105-i may be, for example, a macro eNB 105 having a wired backhaul link (*e.g.*, S1 interface, etc.) to the core network 130-a. Base station 105-i may also communicate with other base stations 105, such as base station 105-m and base station 105-n via inter-base station communication links (*e.g.*, X2 interface, etc.). Each of the base stations 105 may communicate with UEs 115 using different wireless communications technologies, such as different Radio Access Technologies. In some cases, base station 105-i may communicate with other base stations such as 105-m and/or 105-n utilizing base station communication module 1615. In some embodiments, base station communication module 1615 may provide an X2 interface within an LTE/LTE-A wireless communication network technology to provide communication between some of the base stations 105. In some embodiments, base station 105-i may communicate with other base stations through core network 130-a. In some cases, the base station 105-i may communicate with the core network 130-a through network communications module 1665.

[0140] The components for base station 105-i may be configured to implement aspects discussed above with respect to base stations 105 of FIG. 1, FIG. 2, and/or FIG. 10 and may not be repeated here for the sake of brevity. For example, the data transmission module 1310-a may be an example of one or more aspects of the data transmission module 1310, the reduced interference UL subframe module 1320-a may be an example of one or more aspects of the reduced interference UL subframe module 1320, the UCI decoding module 1330-a may be an example of one or more aspects of the UCI decoding module 1330, UL data processing module 1410-a may be an example of one or more aspects of the UL data processing module 1410, UL ACK/NACK transmission module 1420-a may be an example of one or more aspects of the UL ACK/NACK transmission module 1420, and UL retransmission subframe module 1430-a may be an example of one or more aspects of the UL retransmission subframe module 1430. By way of example, these modules may be components of the base station 105-i in communication with some or all of the other components of the base station 105-i via bus system 1680. Alternatively, functionality of these modules may be implemented as a component of the transceiver module 1650, as a computer program product, and/or as one or more controller elements of the processor module 1660.

[0141] The base station 105-i may include antennas 1645, transceiver modules 1650, memory 1670, and a processor module 1660, which each may be in communication, directly or indirectly, with each other (*e.g.*, over bus system 1680). The transceiver modules 1650 may be configured to communicate bi-directionally, via the antennas 1645, with the user equipment 115, which may be a multi-mode user equipment. The transceiver module 1650 (and/or other components of the base station 105-i) may also be configured to communicate bi-directionally, via the antennas 1645, with one or more other base stations 105-j. The transceiver module 1650 may include a modem configured to modulate the packets and provide the modulated packets to the antennas 1645 for transmission, and to demodulate packets received from the antennas 1645. The base station 105-i may include multiple transceiver modules 1650, each with one or more associated antennas 1645.

[0142] The memory 1670 may include random access memory (RAM) and read-only memory (ROM). The memory 1670 may also store computer-readable, computer-executable software code 1675 containing instructions that are configured to, when executed, cause the processor module 1660 to perform various functions described herein (*e.g.*, call processing, database management, message routing, etc.). Alternatively, the software 1675 may not be directly executable by the processor module 1660 but be configured to cause the computer, *e.g.*, when compiled and executed, to perform functions described herein.

[0143] The processor module 1660 may include an intelligent hardware device, *e.g.*, a central processing unit (CPU) such as those made by Intel® Corporation or AMD®, a microcontroller, an application-specific integrated circuit (ASIC), etc. The processor module 1160 may include various special purpose processors such as encoders, queue processing modules, base band processors, radio head controllers, digital signal processors (DSPs), and the like.

[0144] According to the architecture of FIG. 16, the base station 105-i may further include a communications management module 1630. The communications management module

1630 may manage communications with other base stations 105. The communications management module may include a controller and/or scheduler for controlling communications with UEs 115 in cooperation with other base stations 105. For example, the communications management module 1630 may perform scheduling for transmissions to UEs 115 and/or various interference mitigation techniques such as beamforming and/or joint transmission.

[0145] The detailed description set forth above in connection with the appended drawings describes exemplary embodiments and does not represent the only embodiments that may be implemented or that are within the scope of the claims. The term "exemplary" used throughout this description means "serving as an example, instance, or illustration," and not “preferred” or “advantageous over other embodiments.” The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described embodiments.

[0146] Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0147] The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, *e.g.*, a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0148] The functions described herein may be implemented in hardware, software/firmware, or combinations thereof. If implemented in software/firmware , the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software/firmware, functions described above can be implemented using software/firmware executed by, *e.g.*, a processor, hardware, hardwiring, or combinations thereof. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, “or” as used in a list of items prefaced by “at least one of” indicates a disjunctive list such that, for example, a list of “at least one of A, B, or C” means A or B or C or AB or AC or BC or ABC (*i.e.*, A and B and C).

[0149] Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general-purpose or special-purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software/firmware is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

[0150] The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Throughout this disclosure the term “example” or "exemplary" indicates an example or instance and does not imply or require any preference for the noted example. Thus, the disclosure is not to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

CLAIMS

1. A method for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

determining uplink control information (UCI) for transmission to a serving cell during a first uplink (UL) subframe;

determining a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell; and

transmitting the UCI in the reduced interference UL subframe.

2. The method of claim 1, wherein determining the reduced interference UL subframe comprises:

determining a serving TDD configuration of the serving cell;

determining an interfering TDD configuration of the interfering network cell; and

determining, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration.

3. The method of claim 2, wherein determining the interfering TDD configuration of the interfering network cell comprises receiving the interfering TDD configuration from the interfering network cell.

4. The method of claim 1, wherein determining the reduced interference UL subframe comprises:

determining a serving TDD configuration of the serving cell; and

determining the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

5. The method of claim 4, wherein the reduced interference UL subframe comprises the third subframe of every 10 ms radio frame of an LTE type 2 frame structure.

6. A method for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

receiving, at a user equipment (UE), a negative acknowledgement (NACK) from a serving cell associated with data transmitted by the UE in a first uplink (UL) subframe; and

selecting a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe.

7. The method of claim 6, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

8. The method of claim 7, wherein determining the transmission direction of the interfering TDD carrier of the interfering cell for the first UL subframe comprises receiving the TDD configuration of the interfering network cell associated with the interfering TDD carrier.

9. The method of claim 6, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

10. The method of claim 9, wherein the available TDD configurations of the interfering TDD carrier comprise a subset of LTE type 2 frame structure TDD configurations.

11. The method of claim 6, further comprising:

retransmitting the transmitted data in the selected retransmission UL subframe of the TDD carrier.

12. A method for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

transmitting, from a serving cell, one or more data transmissions to a user equipment (UE) over one or more downlink (DL) subframes;

determining a reduced interference UL subframe for receiving uplink control information (UCI) from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell; and decoding the UCI based on the reduced interference UL subframe.

13. The method of claim 12, wherein determining the reduced interference UL subframe comprises:

determining a serving TDD configuration of the serving cell;

determining an interfering TDD configuration of the interfering cell; and

determining, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration.

14. The method of claim 12, wherein determining the reduced interference UL subframe comprises:

determining a serving TDD configuration of the serving cell; and

determining the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

15. A method for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

transmitting, to a user equipment (UE), a negative acknowledgement (NACK) associated with data transmitted by the UE in a first uplink (UL) subframe; and

decoding a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe.

16. The method of claim 15, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

17. The method of claim 15, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

18. An apparatus for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

means for determining uplink control information (UCI) for transmission to a serving cell during a first uplink (UL) subframe;

means for determining a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell; and

means for transmitting the UCI in the reduced interference UL subframe.

19. The apparatus of claim 18, wherein the means for determining the reduced interference UL subframe comprises:

means for determining a serving TDD configuration of the serving cell;

means for determining an interfering TDD configuration of the interfering network cell; and

means for determining, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration.

20. The apparatus of claim 18, wherein means for determining the reduced interference UL subframe comprises:

means for determining a serving TDD configuration of the serving cell; and

means for determining the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

21. An apparatus for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

means for receiving, at a user equipment (UE), a negative acknowledgement (NACK) from a serving cell associated with data transmitted by the UE in a first uplink (UL) subframe; and

means for selecting a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe.

22. The apparatus of claim 21, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

23. The apparatus of claim 21, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

24. An apparatus for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

means for transmitting, from a serving cell, one or more data transmissions to a user equipment (UE) over one or more downlink (DL) subframes;

means for determining a reduced interference UL subframe for receiving uplink control information (UCI) from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell; and

means for decoding the UCI based on the reduced interference UL subframe.

25. The apparatus of claim 24, wherein the means for determining the reduced interference UL subframe comprises:

means for determining a serving TDD configuration of the serving cell;

means for determining an interfering TDD configuration of the interfering cell; and

means for determining, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration.

26. The apparatus of claim 24, wherein the means for determining the reduced interference UL subframe comprises:

means for determining a serving TDD configuration of the serving cell; and

means for determining the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

27. A apparatus for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

means for transmitting, to a user equipment (UE), a negative acknowledgement (NACK) associated with data transmitted by the UE in a first uplink (UL) subframe; and

means for decoding a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe.

28. The apparatus of claim 27, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

29. The apparatus of claim 27, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

30. A computer program product for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

a non-transitory computer-readable medium comprising:

code for causing a computer to determine uplink control information (UCI) for transmission to a serving cell during a first uplink (UL) subframe;

code for causing the computer to determine a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell; and

code for causing the computer to transmit the UCI in the reduced interference UL subframe.

31. The computer program product of claim 30, wherein the non-transitory computer-readable medium further comprises:

code for causing the computer to determine a serving TDD configuration of the serving cell;

code for causing the computer to determine an interfering TDD configuration of the interfering network cell; and code for causing the computer to determine, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration.

32. The computer program product of claim 30, wherein the non-transitory computer-readable medium further comprises:

code for causing the computer to determine a serving TDD configuration of the serving cell; and

code for causing the computer to determine the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

33. A computer program product for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

a non-transitory computer-readable medium comprising:

code for causing a computer to receive, at a user equipment (UE), a negative acknowledgement (NACK) from a serving cell associated with data transmitted by the UE in a first uplink (UL) subframe; and

code for causing the computer to select a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe.

34. The computer program product of claim 33, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

35. The computer program product of claim 33, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

36. A computer program product for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

a non-transitory computer-readable medium comprising:

code for causing a computer to transmit, from a serving cell, one or more data transmissions to a user equipment (UE) over one or more downlink (DL) subframes;

code for causing the computer to determine a reduced interference UL subframe for receiving uplink control information (UCI) from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell; and

code for causing the computer to decode the UCI based on the reduced interference UL subframe.

37. The computer program product of claim 36, wherein the non-transitory computer-readable medium further comprises:

code for causing the computer to determine a serving TDD configuration of the serving cell;

code for causing the computer to determine an interfering TDD configuration of the interfering cell; and

code for causing the computer to determine, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration.

38. The computer program product of claim 36, wherein the non-transitory computer-readable medium further comprises:

code for causing the computer to determine a serving TDD configuration of the serving cell; and

code for causing the computer to determine the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

39. A computer program product for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

a non-transitory computer-readable medium comprising:

code for causing a computer to transmit, to a user equipment (UE), a negative acknowledgement (NACK) associated with data transmitted by the UE in a first uplink (UL) subframe; and code for causing the computer to decode a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe.

40. The computer program product of claim 39, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

41. The computer program product of claim 39, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

42. A communications device for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

at least one processor configured to:

determine uplink control information (UCI) for transmission to a serving cell during a first uplink (UL) subframe;

determine a reduced interference UL subframe of the serving cell corresponding to an UL subframe of an interfering network cell; and

transmit the UCI in the reduced interference UL subframe.

43. The communications device of claim 42, wherein the at least one processor is further configured to:

determine a serving TDD configuration of the serving cell;

determine an interfering TDD configuration of the interfering network cell; and

determine, as the reduced interference UL subframe, a common UL subframe of the serving TDD configuration and the interfering TDD configuration.

44. The communications device of claim 42, wherein the at least one processor is further configured to:

determine a serving TDD configuration of the serving cell; and determine the reduced interference UL subframe based on a common UL subframe of the serving TDD configuration and available interfering TDD configurations.

45. A communications device for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

at least one processor configured to:

receive, at a user equipment (UE), a negative acknowledgement (NACK) from a serving cell associated with data transmitted by the UE in a first uplink (UL) subframe; and

select a retransmission UL subframe for the transmitted data based at least in part on a TDD configuration of a serving cell and a transmission direction of an interfering TDD carrier from an interfering cell for the first UL subframe.

46. The communications device of claim 45, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

47. The communications device of claim 45, wherein the retransmission UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

48. A communications device for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

at least one processor configured to:

transmit, from a serving cell, one or more data transmissions to a user equipment (UE) over one or more downlink (DL) subframes;

determine a reduced interference UL subframe for receiving uplink control information (UCI) from the UE associated with the one or more data transmissions, the reduced interference UL subframe corresponding to an UL subframe of an interfering cell; and

decode the UCI based on the reduced interference UL subframe.

49. The communications device of claim 48, wherein the at least one processor is further configured to:

determine a serving TDD configuration of the serving cell;

determine an interfering TDD configuration of the interfering cell; and

determine, as the reduced interference UL subframe, a common UL subframe of the serving cell TDD configuration and the interfering network cell TDD configuration.

50. The communications device of claim 48, wherein the at least one processor is further configured to:

determine a serving TDD configuration of the serving cell; and

determine the reduced interference UL subframe based on a common UL subframe of the serving cell TDD configuration and available TDD configurations for the interfering cell.

51. A communications device for mitigating interference for time division duplex (TDD) carriers in a wireless communications network, comprising:

at least one processor configured to:

transmit, to a user equipment (UE), a negative acknowledgement (NACK) associated with data transmitted by the UE in a first uplink (UL) subframe; and

decode a retransmitted UL subframe for the transmitted data, the retransmitted UL subframe being selected based at least in part on a TDD configuration of the serving cell and a transmission direction of an interfering TDD carrier for the first UL subframe.

52. The communications device of claim 51, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe.

53. The communications device of claim 51, wherein the retransmitted UL subframe comprises an UL subframe having a same interference profile as the first UL subframe for available TDD configurations of the interfering TDD carrier.

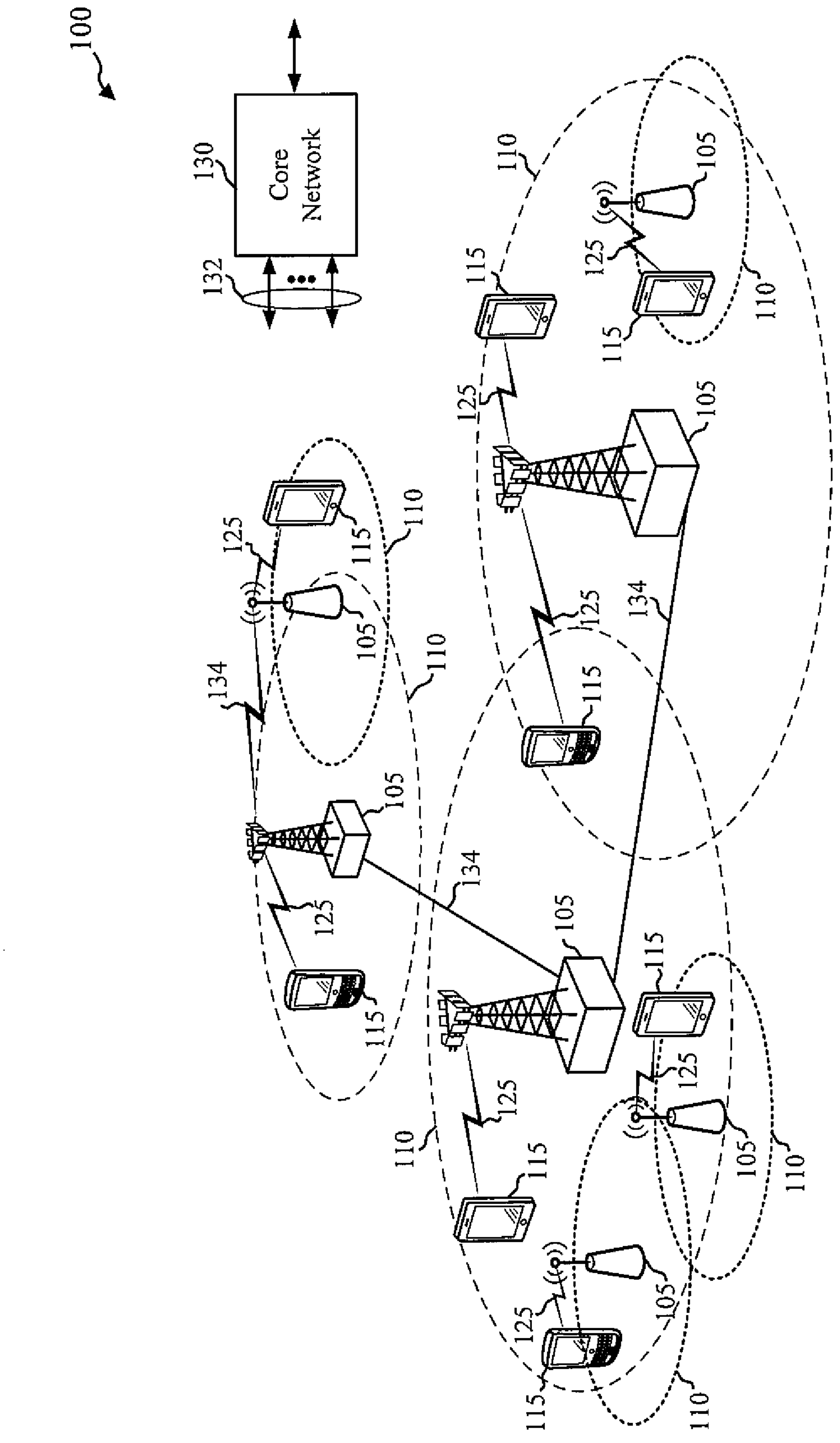

FIG. 1

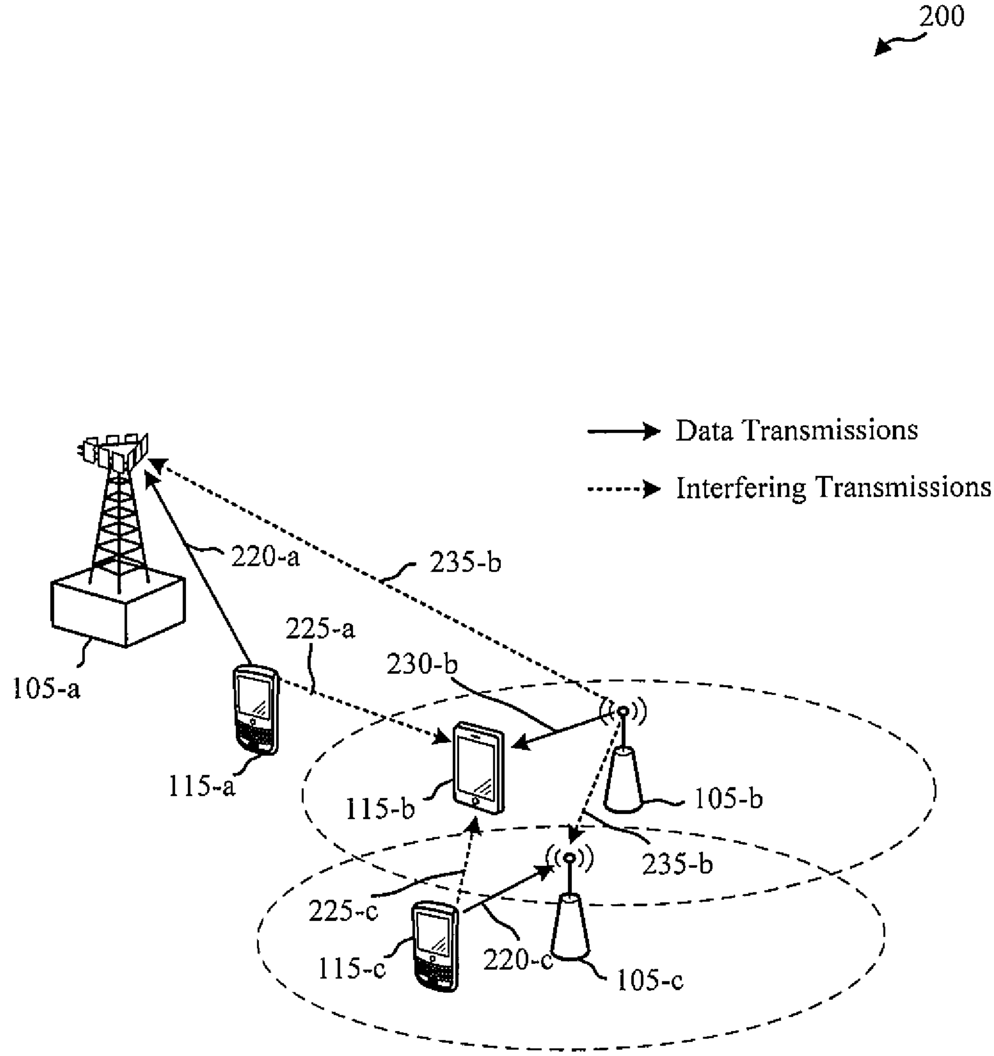
200
Data Transmissions
Interfering Transmissions
220-a
235-b
225-a
230-b
105-a
115-a
115-b
105-b
235-b
225-c
115-c
220-c
105-c

FIG. 2

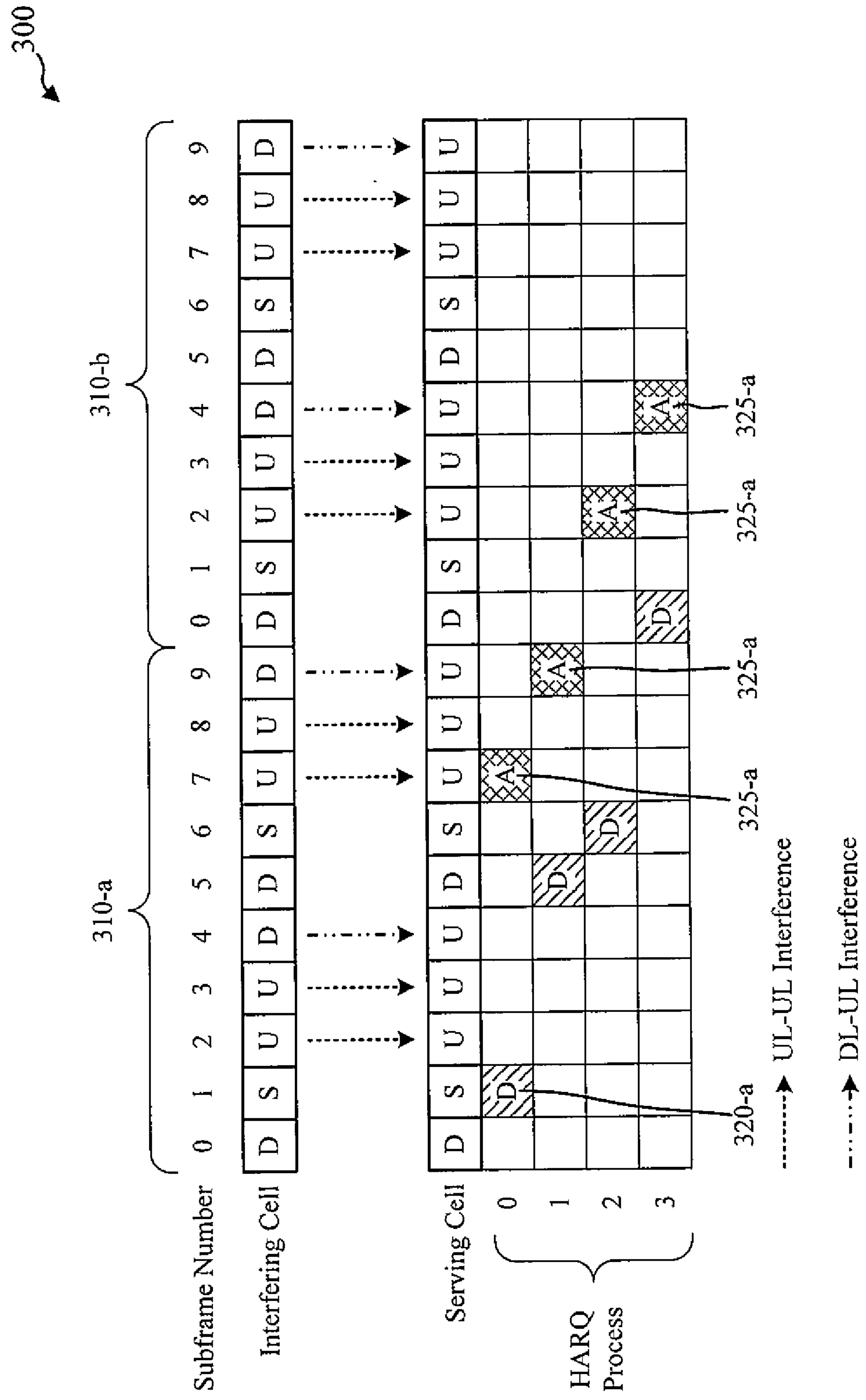
300
310-a
310-b
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
0
1
2
3
320-a
325-a
UL-UL Interference
DL-UL Interference

FIG. 3

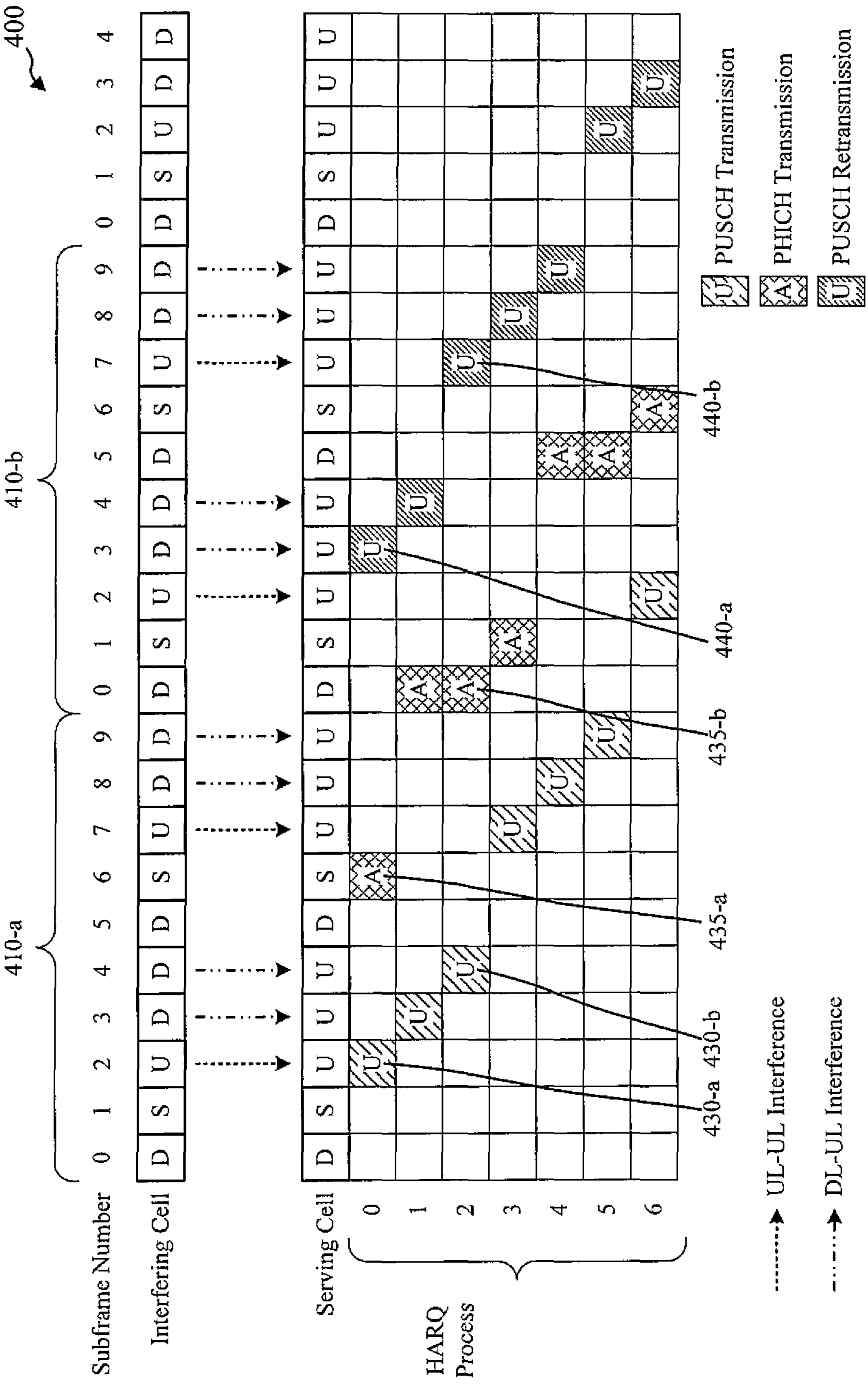
400
410-a
410-b
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
430-a
430-b
435-a
435-b
440-a
440-b
PUSCH Transmission
PHICH Transmission
PUSCH Retransmission
UL-UL Interference
DL-UL Interference

FIG. 4

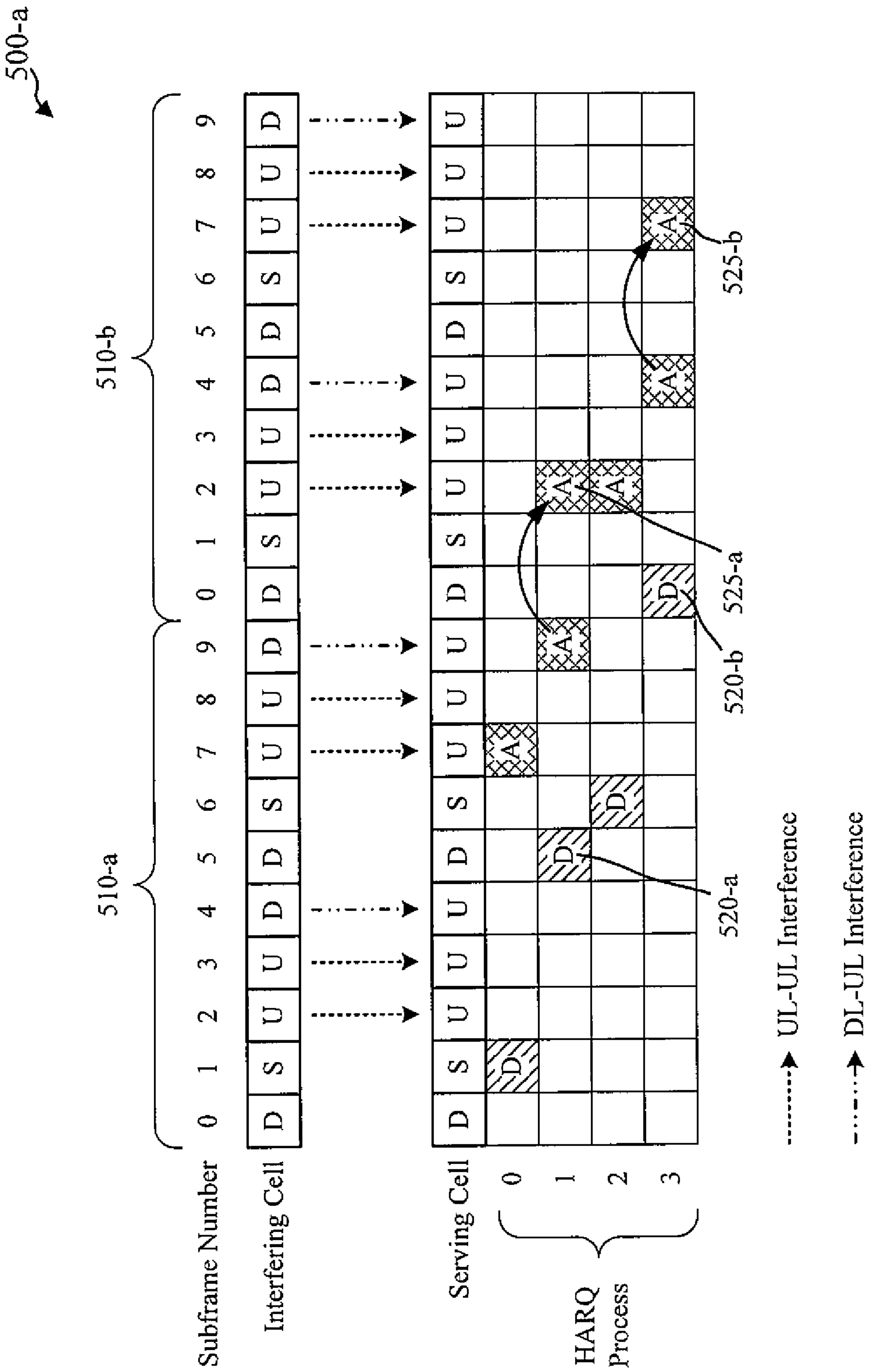
500-a
510-a
510-b
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
520-a
520-b
525-a
525-b
UL-UL Interference
DL-UL Interference

FIG. 5A

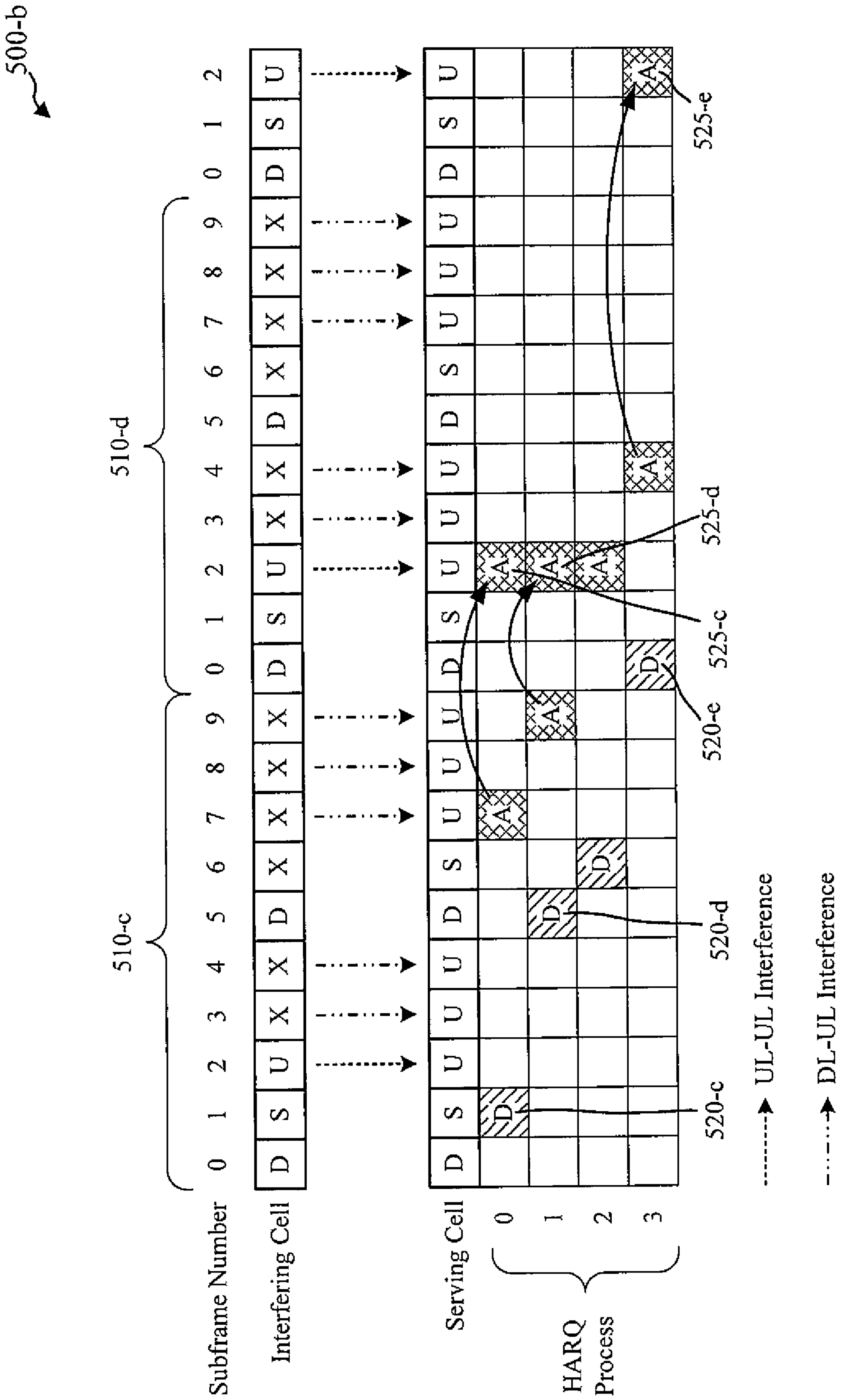
500-b
510-c
510-d
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
520-c
520-d
520-e
525-c
525-d
525-e
UL-UL Interference
DL-UL Interference

FIG. 5B

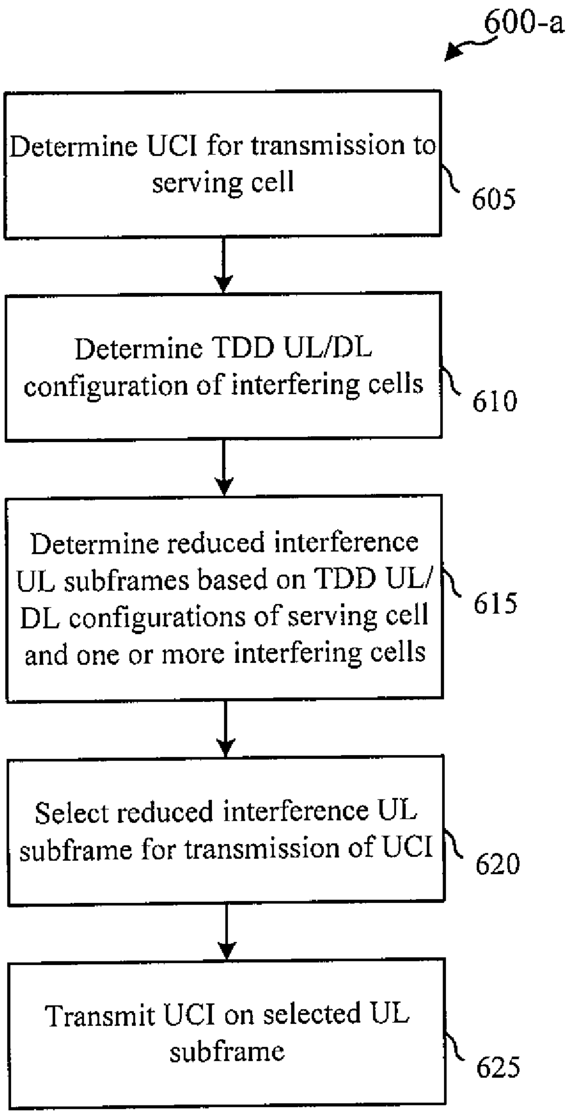
600-a
Determine UCI for transmission to serving cell
605
Determine TDD UL/DL configuration of interfering cells
610
Determine reduced interference UL subframes based on TDD UL/ DL configurations of serving cell and one or more interfering cells
615
Select reduced interference UL subframe for transmission of UCI
620
Transmit UCI on selected UL subframe
625

FIG. 6A

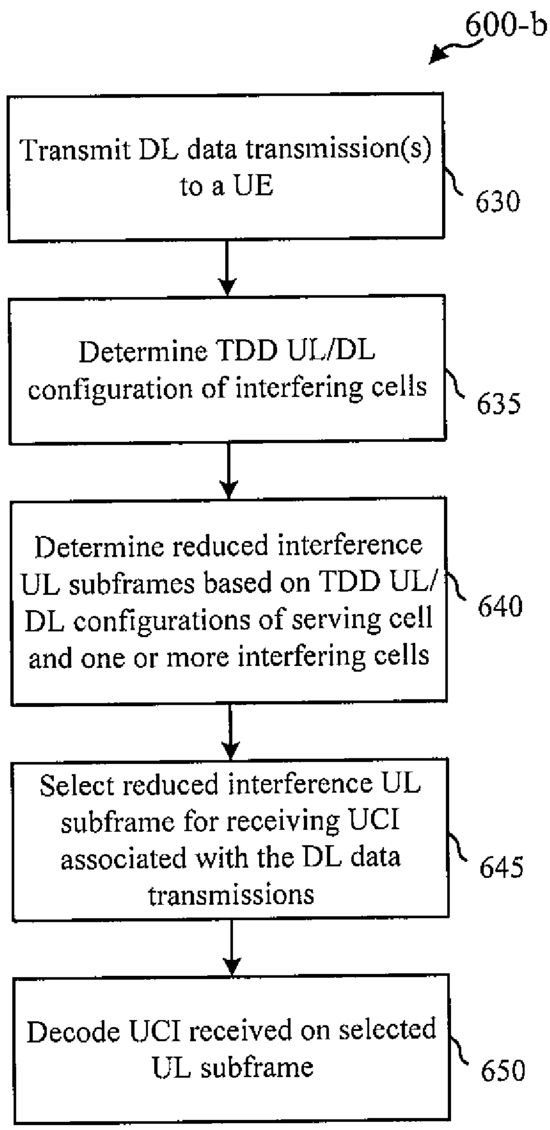
600-b
Transmit DL data transmission(s) to a UE
630
Determine TDD UL/DL configuration of interfering cells
635
Determine reduced interference UL subframes based on TDD UL/ DL configurations of serving cell and one or more interfering cells
640
Select reduced interference UL subframe for receiving UCI associated with the DL data transmissions
645
Decode UCI received on selected UL subframe
650

FIG. 6B

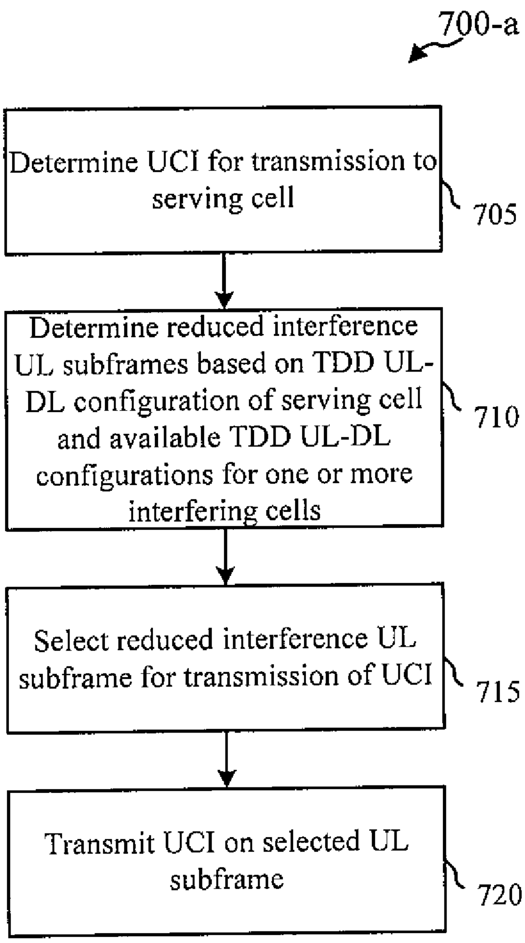
700-a
Determine UCI for transmission to serving cell
705
Determine reduced interference UL subframes based on TDD UL-DL configuration of serving cell and available TDD UL-DL configurations for one or more interfering cells
710
Select reduced interference UL subframe for transmission of UCI
715
Transmit UCI on selected UL subframe
720

FIG. 7A

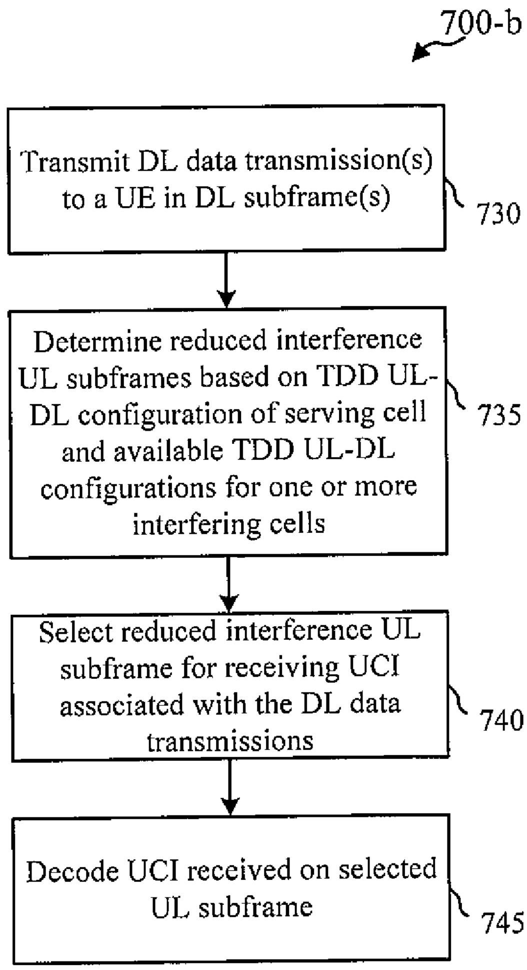
700-b
Transmit DL data transmission(s) to a UE in DL subframe(s)
730
Determine reduced interference UL subframes based on TDD UL-DL configuration of serving cell and available TDD UL-DL configurations for one or more interfering cells
735
Select reduced interference UL subframe for receiving UCI associated with the DL data transmissions
740
Decode UCI received on selected UL subframe
745

FIG. 7B

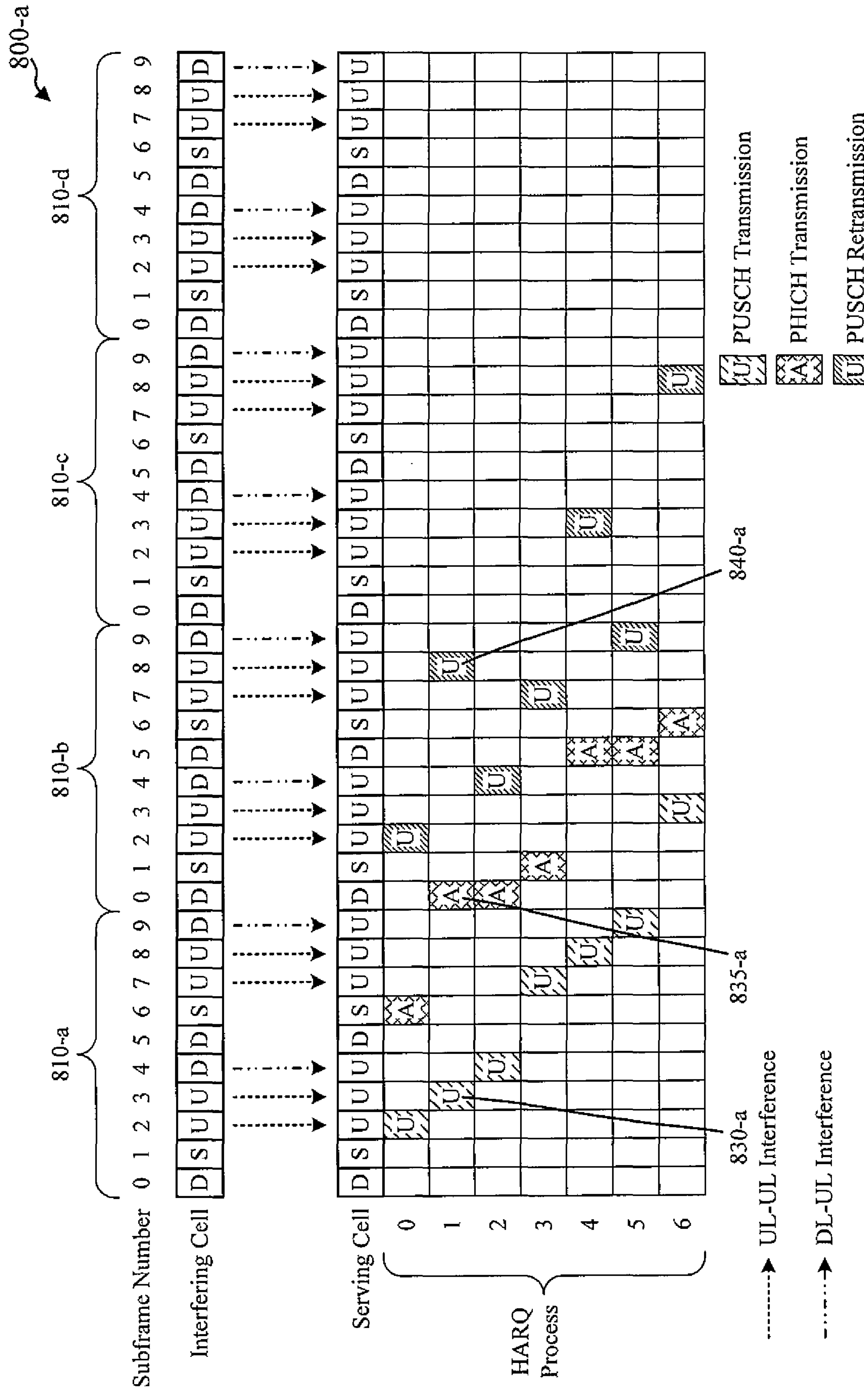
800-a
810-a
810-b
810-c
810-d
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
830-a
835-a
840-a
UL-UL Interference
DL-UL Interference
PUSCH Transmission
PHICH Transmission
PUSCH Retransmission

FIG. 8A

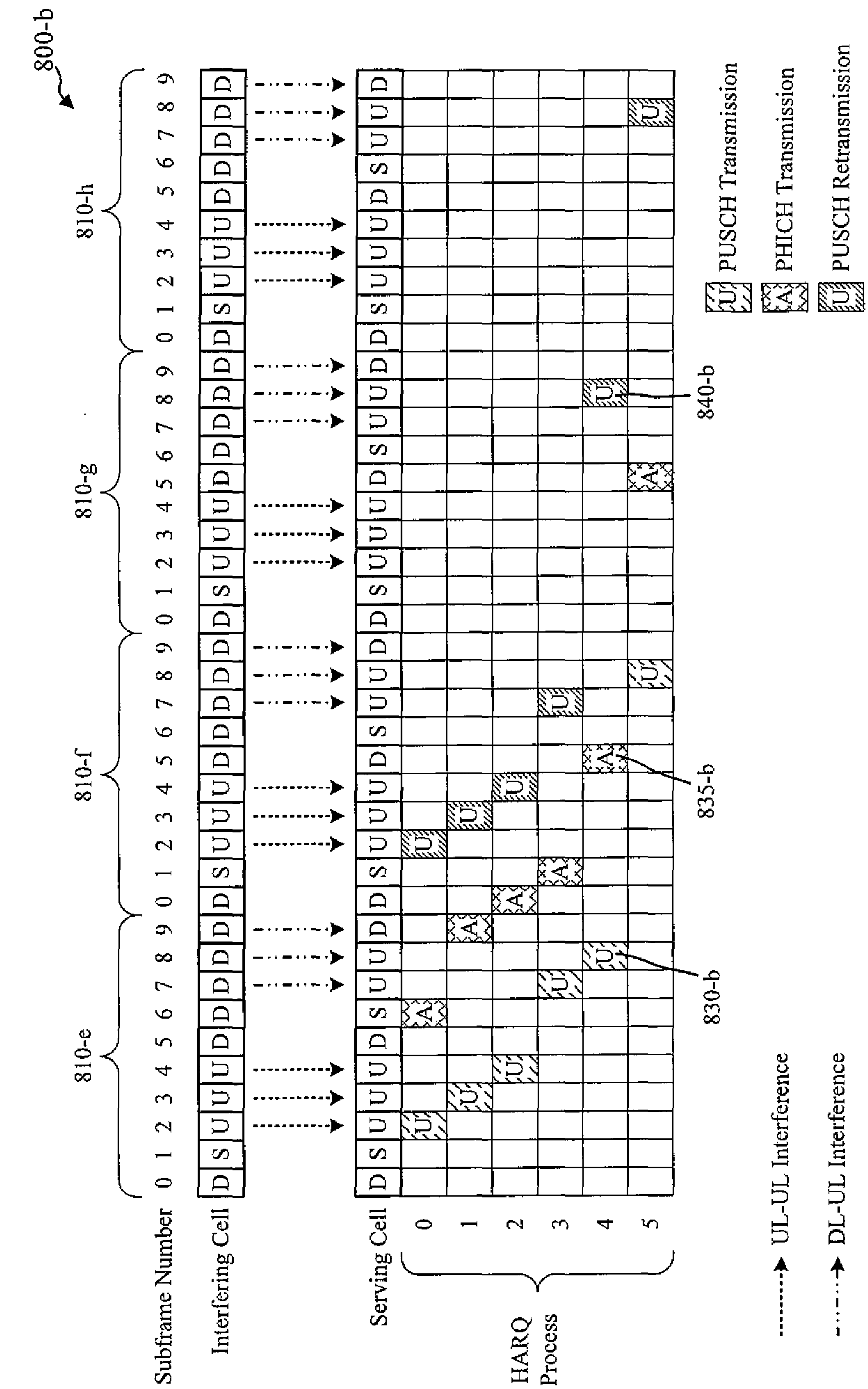
800-b
810-e
810-f
810-g
810-h
Subframe Number
Interfering Cell
Serving Cell
HARQ Process
830-b
835-b
840-b
PUSCH Transmission
PHICH Transmission
PUSCH Retransmission
UL-UL Interference
DL-UL Interference

FIG. 8B

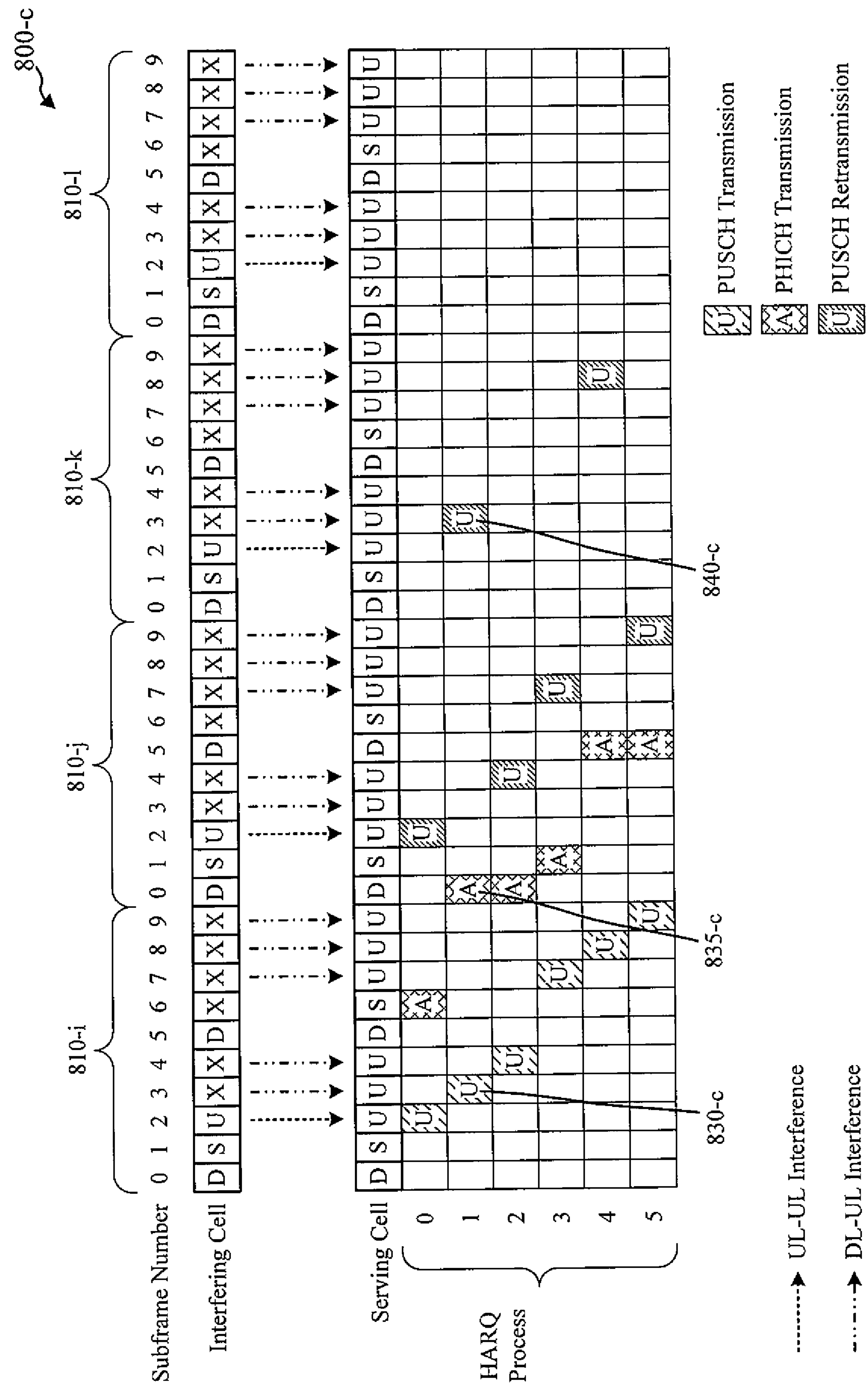
800-c
810-i
810-j
810-k
810-l
Subframe Number
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
Interfering Cell
D S U X X D X X X X D S U X X D X X X X D S U X X D X X X X D S U X X D X X X X
Serving Cell
D S U U U D S U U U D S U U U D S U U U D S U U U D S U U U D S U U U D S U U U
HARQ Process
0
1
2
3
4
5
830-c
835-c
840-c
PUSCH Transmission
PHICH Transmission
PUSCH Retransmission
UL-UL Interference
DL-UL Interference

FIG. 8C

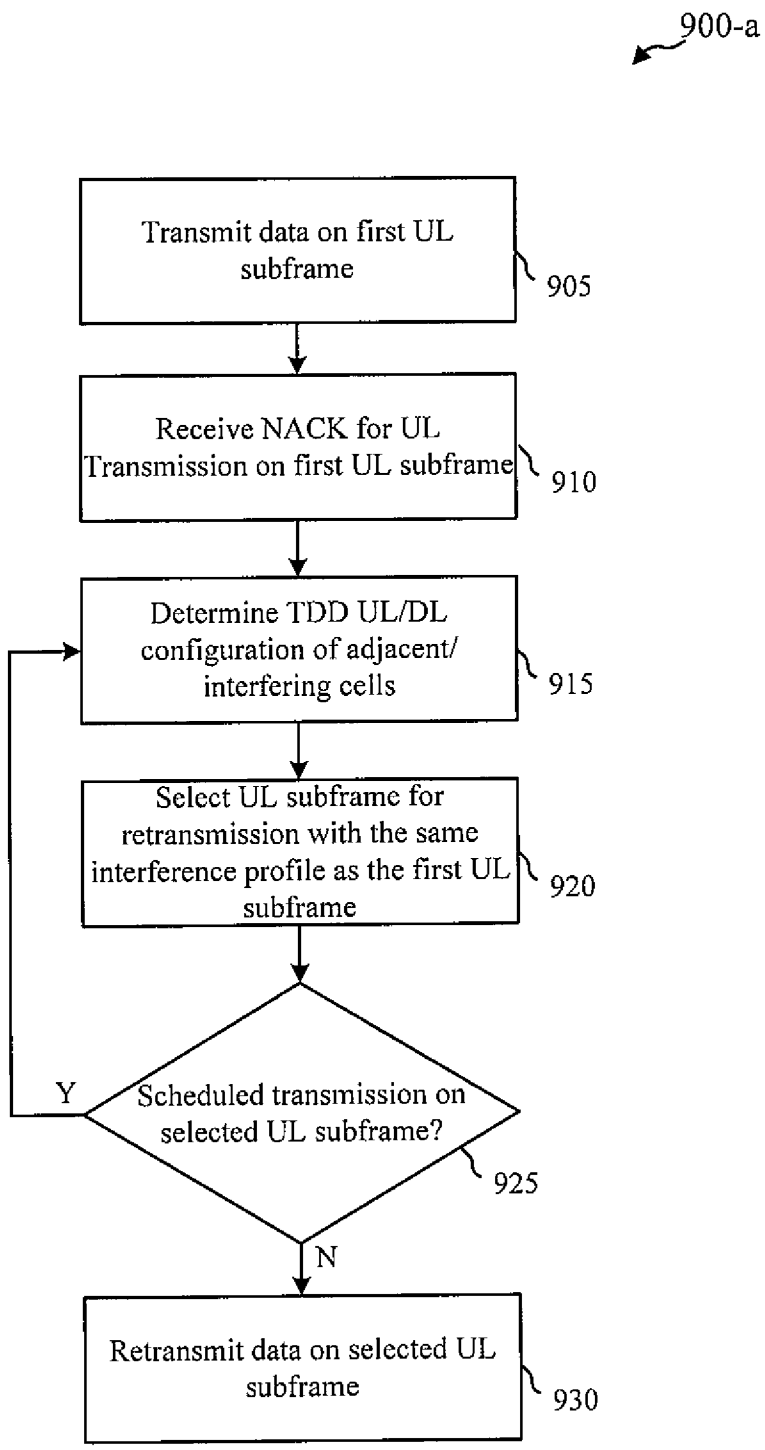
900-a
Transmit data on first UL subframe
905
Receive NACK for UL Transmission on first UL subframe
910
Determine TDD UL/DL configuration of adjacent/ interfering cells
915
Select UL subframe for retransmission with the same interference profile as the first UL subframe
920
Scheduled transmission on selected UL subframe?
Y
N
925
Retransmit data on selected UL subframe
930

FIG. 9A

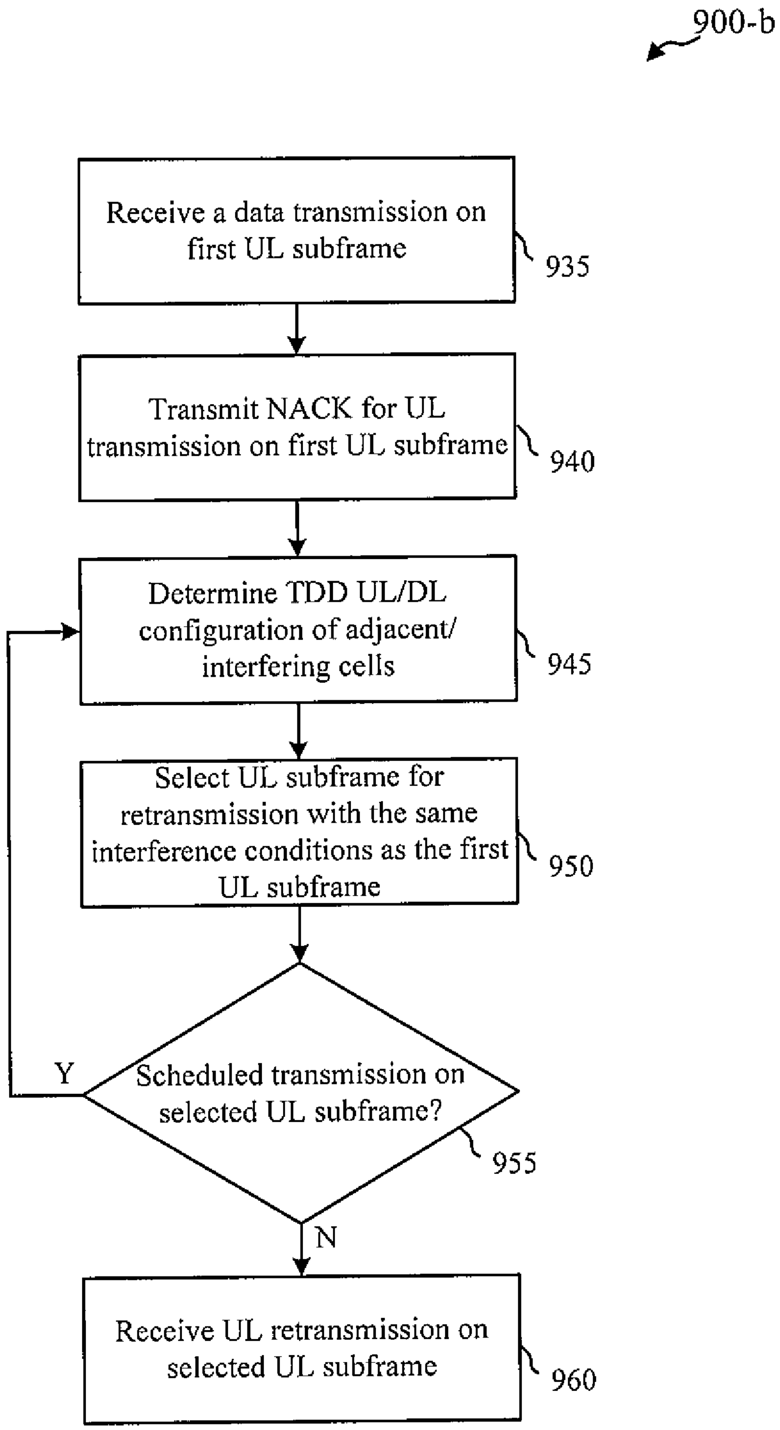
900-b
Receive a data transmission on first UL subframe
935
Transmit NACK for UL transmission on first UL subframe
940
Determine TDD UL/DL configuration of adjacent/ interfering cells
945
Select UL subframe for retransmission with the same interference conditions as the first UL subframe
950
Scheduled transmission on selected UL subframe?
Y
N
955
Receive UL retransmission on selected UL subframe
960

FIG. 9B

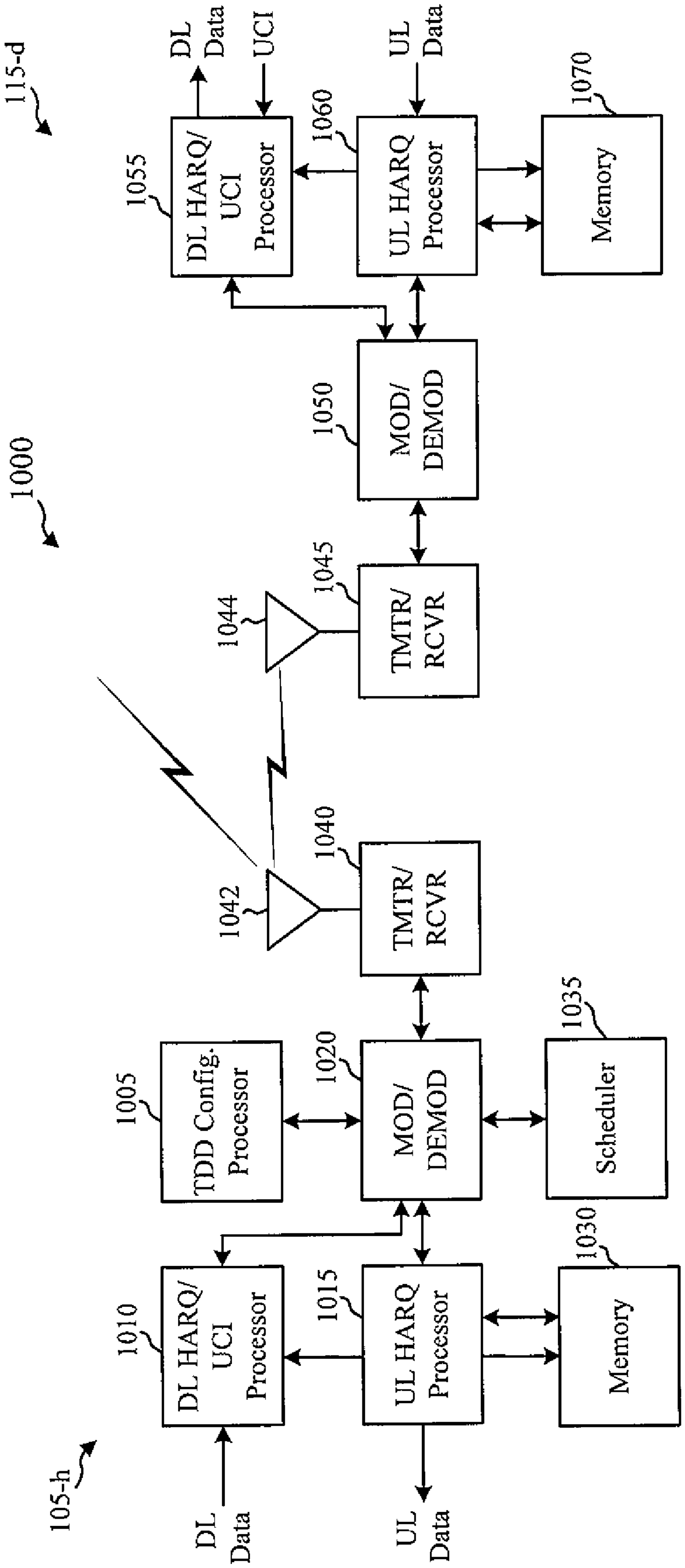
115-d
1000
105-h
DL Data
UCI
DL HARQ/ UCI Processor
1055
UL Data
UL HARQ Processor
1060
Memory
1070
MOD/ DEMOD
1050
TMTR/ RCVR
1045
1044
1042
TMTR/ RCVR
1040
MOD/ DEMOD
1020
TDD Config. Processor
1005
Scheduler
1035
DL HARQ/ UCI Processor
1010
UL HARQ Processor
1015
Memory
1030
DL Data
UL Data

FIG. 10

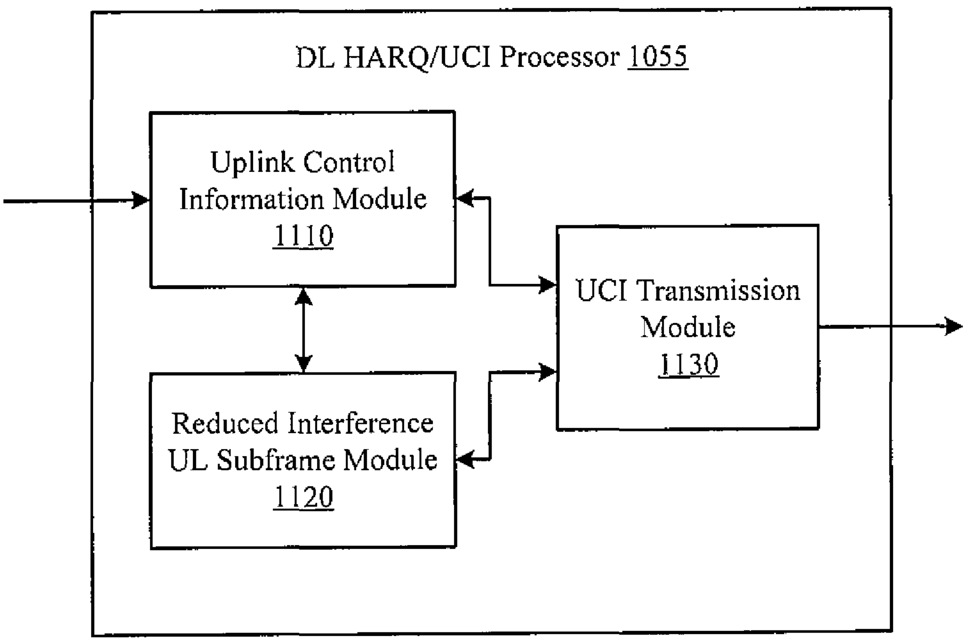
DL HARQ/UCI Processor 1055
Uplink Control Information Module 1110
Reduced Interference UL Subframe Module 1120
UCI Transmission Module 1130

FIG. 11

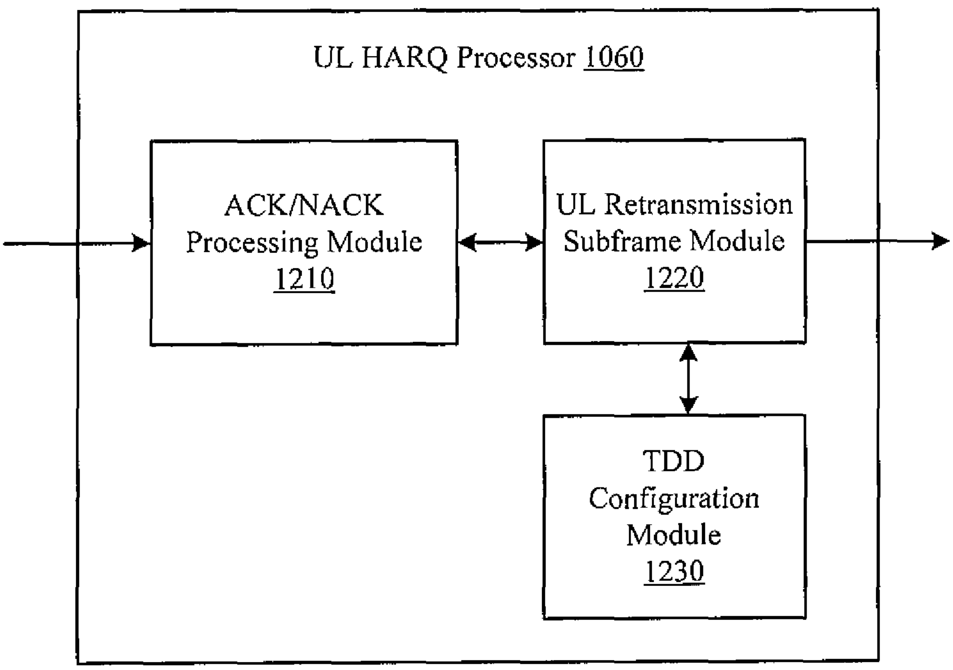
UL HARQ Processor 1060
ACK/NACK
Processing Module
1210
UL Retransmission
Subframe Module
1220
TDD
Configuration
Module
1230

FIG. 12

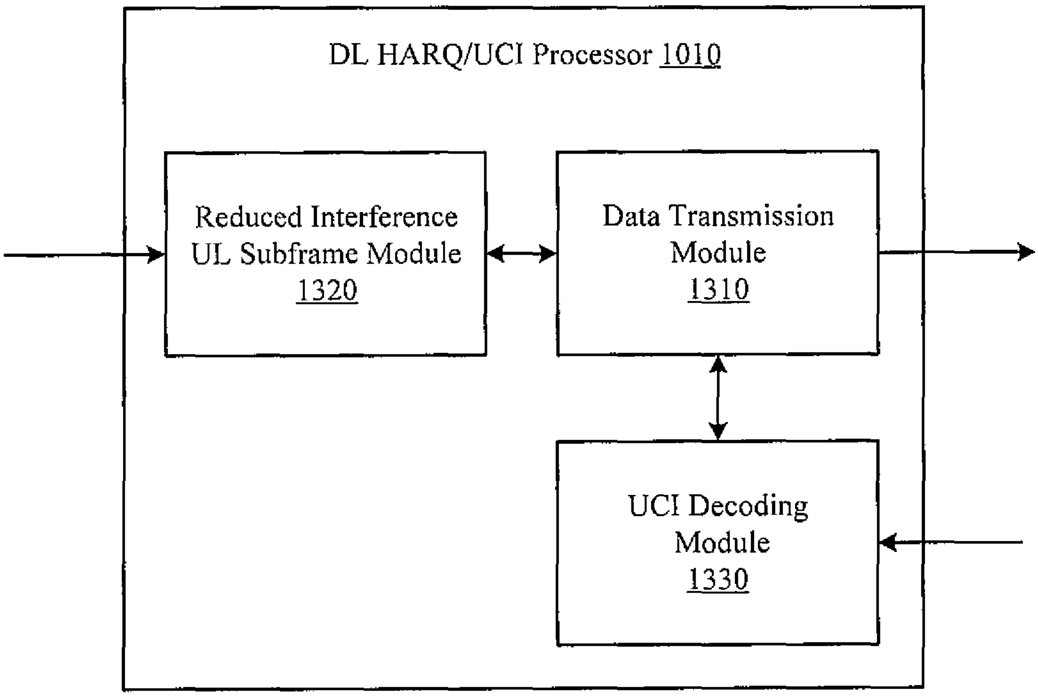
DL HARQ/UCI Processor 1010
Reduced Interference UL Subframe Module 1320
Data Transmission Module 1310
UCI Decoding Module 1330

FIG. 13

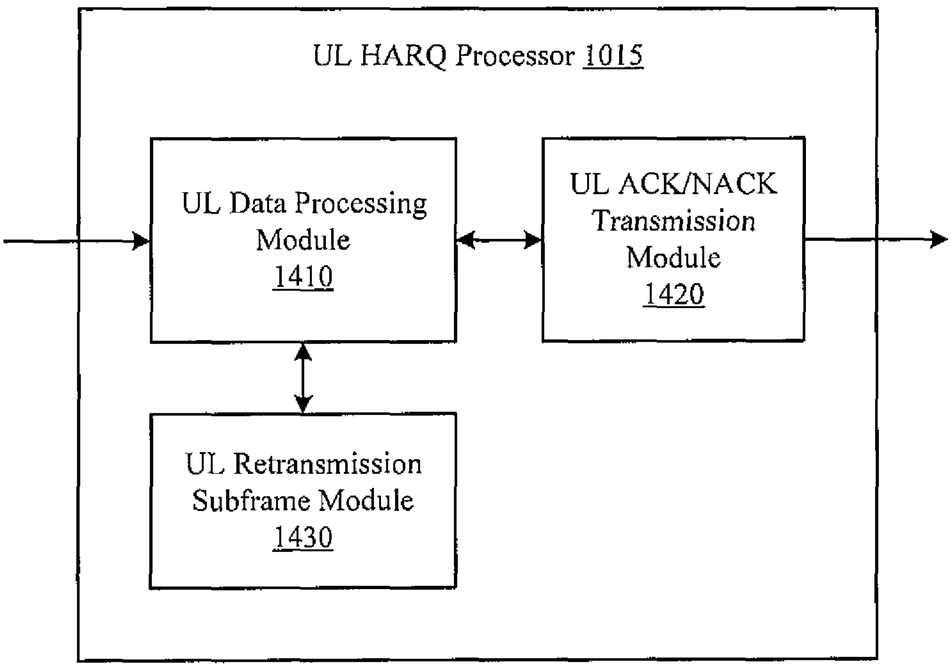
UL HARQ Processor 1015
UL Data Processing Module 1410
UL ACK/NACK Transmission Module 1420
UL Retransmission Subframe Module 1430

FIG. 14

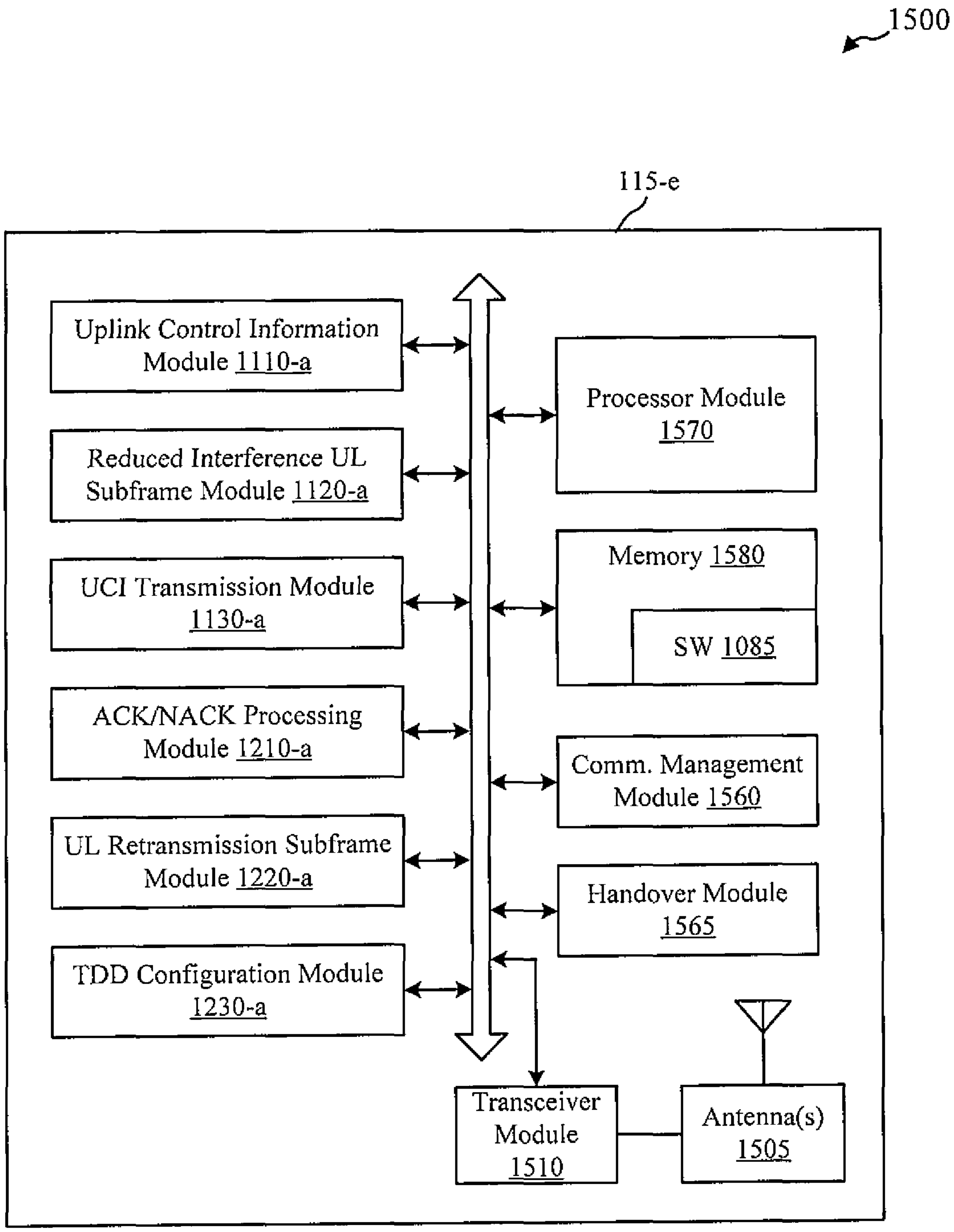
1500
115-e
Uplink Control Information Module 1110-a
Reduced Interference UL Subframe Module 1120-a
UCI Transmission Module 1130-a
ACK/NACK Processing Module 1210-a
UL Retransmission Subframe Module 1220-a
TDD Configuration Module 1230-a
Processor Module 1570
Memory 1580
SW 1085
Comm. Management Module 1560
Handover Module 1565
Transceiver Module 1510
Antenna(s) 1505

FIG. 15

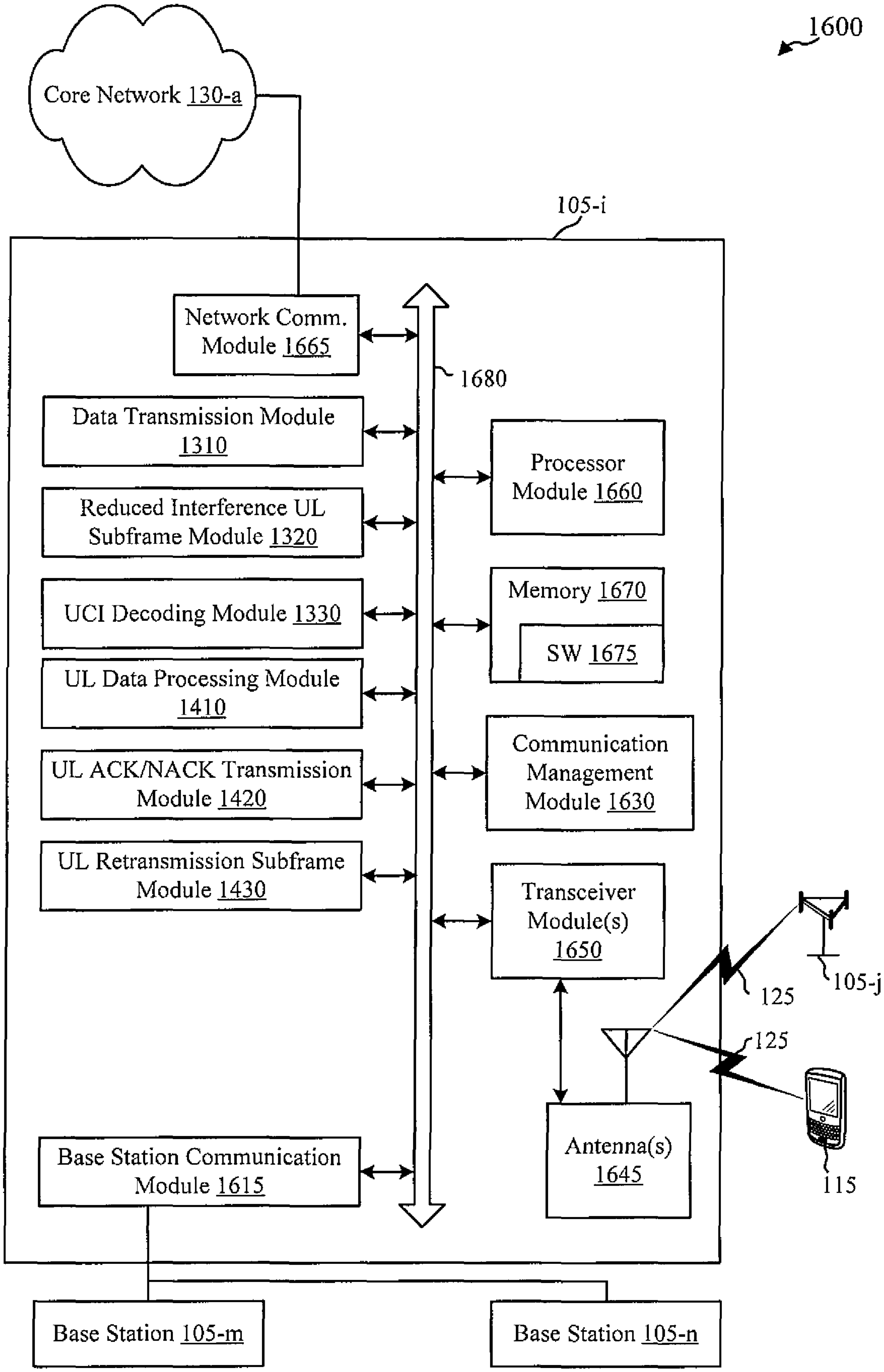
1600
Core Network 130-a
105-i
Network Comm. Module 1665
1680
Data Transmission Module 1310
Processor Module 1660
Reduced Interference UL Subframe Module 1320
Memory 1670
SW 1675
UCI Decoding Module 1330
UL Data Processing Module 1410
Communication Management Module 1630
UL ACK/NACK Transmission Module 1420
UL Retransmission Subframe Module 1430
Transceiver Module(s) 1650
125
105-j
125
Antenna(s) 1645
115
Base Station Communication Module 1615
Base Station 105-m
Base Station 105-n

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2013/000083

A. CLASSIFICATION OF SUBJECT MATTER

See the extra sheet

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: H04L; H04W

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

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

CNABS,CNTXT,CNKI,VEN: mitigat+, reduce+, interfer+, UL, uplink, subframe, shift+, serving w cell, interfering w cell, configur+, TDD, tim+ w division w dulplex

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN102448173A (HUAWEI TECHNOLOGIES CO LTD) 09 May 2012 (09.05.2012) see the whole document	1-53
A	US2012002578A1 (QUALCOMM INC) 05 January 2012 (05.01.2012) see the whole document	1-53
A	CN102804656A (INTEL CORP) 28 November 2012 (28.11.2012) see the whole document	1-53
A	CN101827053A (UNIV QINGHUA) 08 September 2010 (08.09.2010) see the whole document	1-53

☐ 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

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

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

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

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

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

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

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

"&"document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 October 2013 (25.10.2013)	**07 Nov. 2013 (07.11.2013)**

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
WU, Xu
Telephone No. (86-10)62411267

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2013/000083

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN102448173A	09.05.2012	EP2624650A1	07.08.2013
		US20130217402A1	22.08.2013
		WO2011150836A1	08.12.2011
US2012002578A1	05.01.2012	WO2012003382A9	04.10.2012
		JP2013537735W	03.10.2013
		WO2012003382A8	08.11.2012
		CN102971980A	13.03.2013
		WO2012003382A2	05.01.2012
		WO2012003382A3	26.04.2012
		KR20130025439A	11.03.2013
		EP2589175A2	08.05.2013
CN102804656A	28.11.2012	WO2010144182A1	16.12.2010
		US2010317339A1	16.12.2010
		TW201132039A	16.09.2011
		EP2441193A1	18.04.2012
		US8238323B2	07.08.2012
		KR20120024645A	14.03.2012
CN101827053A	08.09.2010	CN101827053B	14.11.2012

Continuation of: Box A in second sheet

CLASSIFICATION OF SUBJECT MATTER

H04W72/08 (2009.01) i

H04W72/12 (2009.01) i