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(54) Title: METHOD, APPARATUS, AND COMPUTER PROGRAM PRODUCT FOR TIME SLOT CONFIGURATION

TTI	1	2	3	4	5	6	7	8	9	10
Subframe	0	1	2	3	4	5	6	7	8	9
donor node	D	S	U	U	**D**	D	S	U	U	**M**
CONFIGURATION 1					↓					↑
RN	D	S	U	U	**M**	D	S	U	U	**D**

FIG. 2

(57) Abstract: Various methods for time slot configuration, for example, within the context of communications implemented within a backhaul or relay link are provided. One example method includes causing establishment of a backhaul link between a donor node and a relay node, and causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings. In this regard, the at least one sub-frame within the baseline sub- frame uplink-downlink pairings maybe implemented as a multicast to downlink sub-frame pairing. Similar and related example methods and example apparatuses are also provided.

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METHOD, APPARATUS, AND COMPUTER PROGRAM PRODUCT FOR TIME SLOT CONFIGURATION

TECHNICAL FIELD

Embodiments of the present invention relate generally to communications management, and, more particularly, relate to a method, apparatus, and a computer program product for time slot configuration within communications systems.

BACKGROUND

The modern communications era has brought about a tremendous expansion of wireless networks. Various types of networking technologies have been developed resulting in unprecedented expansion of computing networks, telephony networks, and the like, fueled by consumer demand. Wireless and mobile networking technologies have addressed related consumer demands, while providing more flexibility and immediacy of information transfer.

As users become increasingly dependant upon wireless networks for business and an person needs, the need for faster and more widely accessible wireless communications increases. In some instances, wireless networks may employ various techniques, such as hardware or software solutions, to increase the bandwidth and transfer rates of the wireless network and to increase coverage of wireless networks. One technique may involve relaying of communications between access points to increase the transfer rates and the coverage provided by a wireless communications system.

BRIEF SUMMARY

Various methods, apparatuses, and computer program products are provided for time slot configuration within a wireless communications system. In this regard, example embodiments of the present invention facilitate communications between a relaying node and a donor node to improve, for example, system bandwidth and/or system coverage. In this regard, example embodiments of the present invention facilitate communications between the relaying node and the donor node in a relaying or backhauling link between the nodes. The communications conducted within the relaying or backhauling link may be conducted in a manner such that the communications do not interfere with communication between the nodes and user equipment (e.g., mobile communications devices).

Various example embodiments of the present invention, define sub-frame time slots according to various configurations to avoid communications interference. In this

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regard, baseline uplink-downlink pairing configurations between the relaying node and the donor node within a time division duplexing environment may be identified and defined for relaying or backhauling link communications. Further, spare sub-frames may also be defined to enable feedback and/or re-transmission of relaying or backhauling link communications in the event that, for example, baseline configurations are insufficient.

One example embodiment is an example method, which comprises causing establishment of a backhaul link between a donor node and a relay node, and causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing. Additionally or alternatively, according to some example embodiments, causing communications includes causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing. Additionally or alternatively, according to some example embodiments, causing communications includes causing communications using inband resources for the backhaul link in a time division duplexing network. Additionally or alternatively, according to some example embodiments, causing communications includes causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration. Additionally or alternatively, according to some example embodiments, the example method includes modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings. Additionally or alternatively, according to some example embodiments, modifying the baseline sub-frame uplink-downlink pairings includes introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

An example apparatus includes at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, direct the apparatus at least to perform causing establishment of a backhaul link between a donor node and a relay node and causing communications via the backhaul link to be conducted in accordance with

baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing. Additionally or alternatively, according to some example embodiments, the apparatus directed to perform causing communications includes being directed to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing. Additionally or alternatively, according to some example embodiments, the apparatus directed to perform causing communications includes being directed to perform causing communications using inband resources for the backhaul link in a time division duplexing network. Additionally or alternatively, according to some example embodiments, the apparatus directed to perform causing communications includes being directed to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration. Additionally or alternatively, according to some example embodiments, the apparatus is further directed to perform modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings. Additionally or alternatively, according to some example embodiments, the apparatus directed to perform modifying the baseline sub-frame uplink-downlink pairings includes being directed to perform introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing. Additionally or alternatively, according to some example embodiments, the apparatus comprises a base station and further comprises communications circuitry and components for establishing the backhaul link. Additionally or alternatively, according to some example embodiments, the communications circuitry and components include at least one antenna.

Another example embodiment is a computer program product comprising at least one computer readable storage medium including computer program code, the computer program code configured to direct an apparatus to at least perform causing establishment of a backhaul link between a donor node and a relay node and causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-

downlink pairings is implemented as a multicast to downlink sub-frame pairing. Additionally or alternatively, according to some example embodiments, the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing. Additionally or alternatively, according to some example embodiments, the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications using inband resources for the backhaul link in a time division duplexing network. Additionally or alternatively, according to some example embodiments, the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration. Additionally or alternatively, according to some example embodiments, the computer program code is further configured to direct the apparatus to perform modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings. Additionally or alternatively, according to some example embodiments, the computer program code configured to direct the apparatus to perform modifying the baseline sub-frame uplink-downlink pairings includes being configured to direct the apparatus to perform introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

Another example apparatus comprises means for causing establishment of a backhaul link between a donor node and a relay node, and means for causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing. Additionally or alternatively, according to some example embodiments, the means for causing communications includes means for causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein

the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing. Additionally or alternatively, according to some example embodiments, the means for causing communications includes means for causing communications using inband resources for the backhaul link in a time division duplexing network. Additionally or alternatively, according to some example embodiments, the means for causing communications includes means for causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration. Additionally or alternatively, according to some example embodiments, the example apparatus further comprises means for modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings. Additionally or alternatively, according to some example embodiments, the means for modifying the baseline sub-frame uplink-downlink pairings includes means for introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1A is an illustration of a communications environment according to various exemplary embodiments of the present invention;

FIG. 1B is a table describing the quadraplex operations of the relay node in time division duplexing according to various exemplary embodiments of the present invention;

FIG. 1C is a table for identifying the time division duplexing uplink and downlink pairing according to various exemplary embodiments of the present invention;

FIGs. 2, 5, 6 and 7 depict time slot configurations according to various exemplary embodiments of the present invention;

FIG. 3 is a table describing example baseline configurations or designs for time division duplexing multicast/broadcast over single frequency network relay uplink-downlink time slot configurations and backhaul link hybrid automatic repeat request data according to various exemplary embodiments of the present invention;

FIG. 4 is a table describing spare sub-frames according to various exemplary embodiments of the present invention;

FIG. 8 is a comprehensive table describing example time slot configurations according to various example embodiments of the present invention;

FIG. 9 is a block diagram of an apparatus for time slot configuration according to various example embodiments of the present invention; and

FIG. 10 depicts a flowchart of a method for time slot configuration according to various example embodiments of the present invention.

DETAILED DESCRIPTION

Embodiments of the present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like reference numerals refer to like elements throughout. As used herein, the terms "data," "content," "information," and similar terms may be used interchangeably to refer to data capable of being transmitted, received, operated on, and/or stored in accordance with embodiments of the present invention. Moreover, the term "exemplary," as used herein, is not provided to convey any qualitative assessment, but instead to merely convey an illustration of an example.

FIG. 1A depicts a communications system including a layer 3 (L3) relay node (RN), or relay cell, with self-backhauling. In some example embodiments, the communications system of FIG. 1A may employ time division duplexing (TDD), where the system may be an Evolved Universal Terrestrial Access Network (EUTRAN) system. As an EUTRAN system, the communications system of FIG. 1A may include any number of EUTRAN node Bs (eNBs), which may provide an Evolved Universal Terrestrial Access (EUTRA) user plane (e.g., packet data convergence protocol (PDCP), radio link control (RLC), medium access control (MAC), physical (layer 1) (PHY), or the like) and control plane (e.g., radio resource control (RRC)) protocol terminations towards a user equipment (UE). The eNBs may be interconnected with each other by means of an interface, refered to as the X2 interface. The eNBs may also be connected by means of a second interface, referred to as the S1 interface, to an evolved packet core (EPC), or, more specifically to a mobility management entity (MME) by means of a S1 MME interface and to a serving gateway (SGW) by means of an S1 interface. The S1 interface may support a many to many relationship between MMEs / Serving Gateways and eNBs.

According to FIG. 1A, the donor node 103 may be an eNB and the RN 100 may employ a relaying technique for self-backhauling to, in some example embodiments, extend coverage and improve capacity. The RN 100 may be party to a relay link 102, which may also be referred to, in some example embodiments as a backhaul link or a donor cell eNB-RN link, with the donor node 103 to, for example, make capacity available for communications with the UE 101, which may be a release-8 (Rel-8) UE. The RN 100 and the donor node 103 may utilize inband resources for the relay link in a TDD network to provide an efficient solution for self-backhauling. In this regard, some example embodiments of the present invention address the TDD uplink (UL) downlink (DL) time slot configuration for the donor node 103 and the RN 100, and Rel-8 UE backwards compatibility.

The RN 100 node may also be an eNB supporting one or more cells or sectors. The RN 100 may be accessible to Rel-8 UEs (e.g., UE 101) and may provide DL common and shared control signaling, (e.g., primary synchronization channel (P-SCH), secondary synchronization channel (S-SCH), physical broadcast channel (P-BCH), common reference signal (CRS)), to allow UEs to access the L3 RN 100. The RN 100 may be wirelessly connected to the rest of the radio access network (RAN) via donor node 103, which may provide a larger coverage area. By utilizing the relay link 102, a self-backhauling technique is employed, where the S1 and X2 interfaces use wireless inband or outband resources. Some example embodiments of the present invention consider the utilization of inband resources in a self-backhauling technique. By employing a backhauling technique, flexibility is brought to the system. However, particularly as the number of UEs connected to the RN 100 increases, bandwidth is utilized to support the self-backhauling technique.

In some situations, for example, when relay link 102 uses in-band resources, interference may occur between the relay link 102 and the communications with a UE. In particular, downlink transmissions to UEs may interfere with the downlink reception from the donor node 103 with respect to the relay link 102. Accordingly, various example embodiments of the present invention provide mechanisms for preventing this and other interference. Further, some example embodiments, also support service to Rel-8 UEs by the RN 100. In some example embodiments, service to Rel-8 UEs by the RN 100 may be provided in a same sub-frame as the RN 100 is communicating with the donor node 103.

To communicate with both the UE and the donor node simultaneously a quadruplex frame structure may be utilized as illustrated in Figure 1B. When the RN is in

the receive mode (DL time slot in donor node cell) or transmit mode (UL time slot in donor node cell) on the relay link in sub-frame i and i+2, respectively, the RN may not, at the same time, be in the transmit mode (DL timeslot in RN cell) or receive mode (UL timeslot in RN cell) on the RN UE link. However, in some example embodiments, this may be possible in the sub-frame i+1 and i+3, respectively.

The shaded blocks in the second row in FIG. 1B indicate the operation for the donor node attached UE, while the unshaded blocks in the second row indicate the operation for the RN attached UE. Hence, an RN attached UE may effectively see the L3 relay disappear in sub-frame i and i+2. An unaware Rel-8 UE may attempt to interpolate the CRS in sub-frames i and i+1, i+1 and i+2, i+2 and i+3, .., where CRSs are only transmitted by the RN in sub-frame i+1. This may generate erroneous results if the Rel-8 UE does not know of an employed relaying solution. In this regard, under certain hardware constraint limitations, an issue may arise when RN 100 is receiving data from the donor node 103, such that the RN 100 may not be able to simultaneously transmit data or control to attached UEs. As stated above, a rel-8 UE in the cell of the RN 100 that is unaware that the relaying scheme is being employed may attempt to interpolate a CRS in an all DL sub-frame. As a result, incorrect channel estimation by the UE may occur.

To remedy these and other issues, various example embodiments of the present invention utilize a TDD multicast/broadcast over single frequency network (MBSFN) relay UL-DL time slot configuration scheme. As further described below, example embodiments of the present invention operate with respect to UL-DL pairings between time slots based on the configurations described in FIG. 1C. According to the timing described with respect to FIG. 1B, pairing within a sub-frame of the different UL-DL configurations may be defined as further described below, where according to some example embodiments, the configuration number is referred to as the configuration with respect to the RN cell.

Various example embodiments of the present invention focus on the use of inband resources for the relay link in a TDD network, also referred to as the backhaul link, to provide an efficient solution for self-backhauling. In particular, the TDD UL DL time slot configuration for the donor cell and the RN, and the Rel-8 UE backwards compatibility aspects, are considered and addressed by various example embodiments of the present invention. Example embodiments of the present invention have no negative impacts on UL performance, and address near-far interference issues. Additionally, in

some example embodiments, hybrid automatic repeat request (HARQ) aspects are also considered.

According to various example embodiments, the donor node 103 and the RN 100 may communicate via the relay link 102 using a TDD UL-DL time slot configuration. In this regard, for the UL of the relay link, one DL sub-frame of the donor node 103 may be configured as an MBSFN sub-frame, and RN 100 may transmit data and control information to the donor node 103 in the last several symbols within the MBSFN sub-frame. Time slots configured in this manner may be referred to as being in an [M D] configuration, since there is an MBSFN sub-frame in the cell of donor node 103 (represented by the "M"), and a DL sub-frame in the cell of RN 100 (represented by the "D").

Alternatively, for the DL of the relay link, one DL sub-frame for the RN 100 may be configured as an MBSFN sub-frame, and the donor node 103 may transmit data and control information to the RN 100 in the last several symbols within the MBSFN sub-frame. Time slots configured in this manner may be referred to as being in an [D M] configuration, since there is a DL sub-frame for the cell of donor node 103 (represented by the "D"), and an MBSFN sub-frame in the cell of the RN 100 (represented by the "M").

More particularly, FIG. 2 depicts an example configuration of time slots in accordance with various example embodiments of the present invention. In FIG. 2, the sub-frames may be defined as "U" for an uplink sub-frame, "D" for a downlink sub-frame, "M" for an MBSFN sub-frame, or "S" for a special sub-frame. FIG. 2 depicts a first configuration for both donor node cells and RN cells, e.g., with a DL-UL switching point of periodicity of 5 ms. In the first 5 ms, sub-frame #4 in RN cell may be configured as M, that is a MBSFN relay sub-frame, while in the donor node cell sub-frame #4 may be a D, that is a DL sub-frame. By defining the time slots in this manner, relay link transmissions from the donor node to the RN may be performed in the time slot. In the second 5ms, sub-frame #9 may be configured for RN to donor node relay link transmissions. Accordingly, sub-frame #9 may be configured as an MBSFN sub-frame in the donor node cell, and kept as a DL sub-frame in the RN cell.

In this regard, both UL and DL transmission for relay link may be performed by defining or redefining some DL sub-frames in the donor node cell or RN cell. As such, according to some example embodiments, UL performance is not impacted, which is critical for some TDD UL-DL configurations where several downloads or downlinks are

related to one upload or uplink. Further, since control signaling (e.g., physical downlink control channel (PDCCH) and physical HARQ indicator channel(PHICH)) and CRS may be transmitted via the first 2 symbols in an MBSFN sub-frame, in some example embodiments, the configurations will not impact the UL HARQ process in the donor node cell or the RN cell.

Additionally, considering the scheme described with respect to FIG. 2, the RN to donor node relay link transmission may be realized by configuring both Ds in the donor node and RN cells into Ms. For example, in FIG. 2, sub-frame #9 may be configured in the RN cell to be an MBSFN sub-frame, and therefore, RN may also transmit data and control information to the donor node cell in the last several symbols in the sub-frame. Similar to using [M D] (M in donor node cell and D in RN cell), in some example embodiments, an [M M] configuration (both donor node and RN cells use MBSFN sub-frame configuration) may be implemented. An [M M] configuration may have no impact on the HARQ process in RN cell or the relay link. A distinction with respect to an [M M] configuration may be that DL throughput in the RN cell may be impacted since no DL data transmission exists in the MBSFN sub-frame. Further, one direction transmission in an [M M] configuration may be performed since, in some example embodiments, no simultaneous transmissions may be performed from RN to UE when RN is transmitting to the donor node.

In this regard, according to some example embodiments, interference with the donor node's reception in the later part of the M frame may be avoided in, for example an [M D] configuration, by not scheduling UEs in the corresponding D frame. Additionally, the Reference Symbols (RS) in the latter part of the D sub-frame may also impact the reception at the donor node, and configuring the M subframe may avoid interference with the reference symbols as well. Also, in some example embodiments, a blank sub-frame may be used instead of an MBSFN sub-frame, if the UEs support such a configuration.

Additionally, in some example embodiments, baseline designs for TDD MBSFN relay UL-DL time slot configurations may also be considered with respect to backhaul (or relay) link HARQ. In this regard, a D sub-frame may be selected in the donor node or RN cell that may be configured as an M to enable backhaul link UL or DL transmissions. Note, however, according to some example embodiments, TDD configuration #0 from FIG. 1C need not be used since sub-frame #0, 1, 5, and 6 need not be configured as an MBSFN sub-frame.

For TDD configurations #1 thorugh #6, example baseline designs for TDD MBSFN relay UL-DL time slot configurations and backhaul link HARQ are described with respect to FIG. 3. The baseline designs include one UL/DL backhaul link HARQ process for each TDD configuration. For example, for TDD UL/DL configuration #1, sub-frame #4 and #9 may be paired for backhaul link configurations. In this case, two different settings may be utilized. In a first example setting, sub-frame #4 is for the donor node to RN backhaul link, which means the donor node cell is configured as a "D" and the RN cell is configured as an "M" as shown in FIG. 2, and sub-frame #9 in this case is configured for a RN to donor node backhaul link, which is [M D] as shown in FIG. 2. In a second example setting, sub-frame #4 may be configured as an [M D], and sub-frame #9 may be configured as a [D M]. Further, in some example embodiments, the feedback delay for either setting, may be 5ms, and HARQ round trip time (RTT) may be 10ms.

The baseline design for backhaul link HARQ may then be realized in that an acknowledge or negative acknowledge may be in the first available backhaul link sub-frame after 3ms, and DL/UL retransmission may be in the next DL/UL RN cell sub-frame. In other cases, for example, for TDD UL/DL configuration #2 and #5, pairing sub-frame #3 and #8 or pairing sub-frame #4 and #9 may provide similar HARQ RTT and feedback delay.

Additionally, spare TDD MBSFN relay UL-DL time slot configurations and backhaul link HARQ designs may be considered. In situations where the baseline time slot configurations and HARQ designs are insufficient for backhaul link data transmissions, spare sub-frames may be utilized. The spare design may serve as a complementary design to the baseline configurations. The spare designs may be available for TDD UL/DL configuration #2, #3, #4 and #5, which have more than two D sub-frames available to the backhaul link. The spare sub-frame for the backhaul link is summarized in FIG 4.

The spare sub-frames listed in FIG. 4 may be configured for the backhaul link based on a rule set. In this regard, in some example embodiments a spare sub-frame may be configured as either a donor node to RN or a RN to donor node backhaul transmission (e.g., according to traffic load status). Further, in some example embodiments, once configured, one more UL or DL HARQ process may be available to the backhaul link. Additionally, in some example embodiments, the HARQ for spare sub-frame may be structured such that the feedback of the HARQ process may reside in the first available backhaul link sub-frame after 3ms and/or the retransmission of this HARQ process may

also occur in the spare sub-frame. In this regard, it is noteworthy that these and other aspects of the present invention make a relaying solution feasible to TDD UL/DL configuration #5, in addition to the other configurations.

Accordingly, TDD MBSFN relay UL-DL time slot configurations may be implemented based on the principles described above and otherwise described herein. For additional depth of disclosure, some baseline designs for backhaul link time slot configurations are provided. According to some example embodiments, a TDD UL-DL configuration for configuration #0 may not be feasible. Further, a TDD UL-DL configuration for configuration #1 may be separated into two settings. In a first setting, sub-frame #4 may be defined as a [D M] and sub-frame #9 may be defined as a [M D]. In a second setting, sub-frame #9 may be defined as a [D M] and sub-frame #4 may be defined as a [M D].

Further, a TDD UL-DL configuration for configuration #2 may be separated into four settings. In a first setting sub-frame #3 may be defined as a [D M] and sub-frame #8 may be defined as a [M D]. In a second setting, sub-frame #8 may be defined as a [D M] and sub-frame #3 may be defined as a [M D]. In a third setting, sub-frame #4 may be defined as a [D M] and sub-frame #9 may be defined as a [M D]. Further, in a fourth setting sub-frame #9 may be defined as a [D M] and sub-frame #4 may be defined as a [M D].

A TDD UL-DL configuration for configuration #3 may be separated into two settings. In a first setting, sub-frame #8 may be defined as a [D M] and sub-frame #9 may be defined as a [M D]. In a second setting, sub-frame #9 may be defined as a [D M] and sub-frame #8 may be defined as a [M D].

A TDD UL-DL configuration for configuration #4 may be organized similar to the TDD UL-DL configuration for configuration #1. A TDD UL-DL configuration for configuration #5 may be organized similar to the TDD UL-DL configuration for configuration #2. Further, for configuration #6, a TDD UL-DL configuration may include a first setting where sub-frame #9 in first 10ms may be defined as a [D M] and sub-frame #9 in next 10ms may be defined as a [M D]. Additionally, or alternatively, for all the above configurations, an [M D] may also be configured as a [M M], which means that the RN cell may also have MBSFN sub-frame. A modification in this regard, according to some example embodiments, will not impact the UL HARQ in the RN cell.

In addition to the baseline configurations or designs described above, spare sub-frames may also be configured for the backhaul link. One example configuration is given

in FIG. 5. Accordingly, in addition to sub-frame #3 (in [M D]) pairing with sub-frame #8 (in [D M]), one spare sub-frame #9 may also be configured to [D M]. In this manner, the backhaul link will gain an additional DL HARQ process. The spare sub-frame may be flexibly configured as [D M] or [M D] according to, for example, the backhaul link traffic load. According to various example embodiments, some available spare sub-frames for different TDD UL-DL configurations are shown in FIG. 4.

According to some example embodiments, the HARQ for backhaul link may be designed such that acknowledgements and negative acknowledgements may be in the first available backhaul link sub-frame after 3ms, and DL or UL retransmission may be in the next DL or UL baseline relay sub-frame. For example, in FIG. 6, sub-frame #3 and #8 are configured as [D M] and [M D], respectively for TDD UL-DL configuration #5. In this example, the UL feedback for sub-frame #3 may be in sub-frame #8, while the retransmission (e.g., if a negative acknowledgement is performed) may be in sub-frame #3 in the next 10ms.

Additionally, if a spare sub-frame is also configured for the backhaul link, the HARQ design may be generated such that the HARQ design for baseline backhaul configurations need not be impacted, the feedback of the DL or UL HARQ process may reside in the first available backhaul link UL or DL sub-frame after 3ms and the retransmission of this HARQ process may also occur in this spare sub-frame. One example for TDD configuration #4 is also shown in FIG. 7, in which sub-frame #4 plus sub-frame #9 are, for example, baseline configurations, and spare sub-frame #7 is also configured to be defined as a [D M] to give an additional backhaul DL HARQ process. In this case, the HARQ designs for sub-frame #4 and sub-frame #9 need not be impacted (thus not shown in the figure for simplicity). Sub-frame #7 may be utilized in the first 10ms and the UL feedback may be in sub-frame #9 in the second 10ms, while the corresponding re-transmission may be in sub-frame #7 of the third 10ms, if necessary.

FIG. 8 is a table describing various aspects of the present invention. The table of FIG. 8 describes example embodiments with respect to baseline sub-frame parings for various TTD UL/DL configurations. With respect to the sub-frame parings, spare sub-frames for HARQ processes are also defined.

The description provided above illustrates example methods, apparatuses, and computer program products for time slot configuration in accordance with various example embodiments of the present invention. FIG. 9 illustrates another example embodiment of the present invention in the form of an example apparatus 300 that may be configured to perform various aspects of the

present invention as described herein. The apparatus 300 may be configured to perform the role of the relaying node 100, the donor node 103, or both. In some exemplary embodiments, the apparatus 300 may be configured to operate in accordance with the UE 101.

In some exemplary embodiments, the apparatus 300 may be embodied as, or included as a component of, a communications device with wired or wireless communications capabilities. Some examples of the apparatus 300, or devices that may include the apparatus 300, may include a base station, an access point (including a fempto-node), a computer, a server, a mobile terminal such as, a mobile telephone, a portable digital assistant (PDA), a pager, a mobile television, a gaming device, a mobile computer, a laptop computer, a camera, a video recorder, an audio/video player, a radio, and/or a global positioning system (GPS) device, a network entity, or any combination of the aforementioned, or the like. Further, the apparatus 300 may be configured to implement various embodiments of the present invention as described herein including, for example, various exemplary methods of embodiments of the present invention, where the methods may be implemented by means of a hardware or computer program product configured processor, computer-readable medium, or the like.

The apparatus 300 may include or otherwise be in communication with a processor 305, a memory device 310, and a communications interface 315. In some embodiments, the apparatus 300 may also include a user interface 325 and a slot configuration manager 340. The processor 305 may be embodied as various means including, for example, a microprocessor, a coprocessor, a controller, or various other processing devices including integrated circuits such as, for example, an ASIC (application specific integrated circuit), an FPGA (field programmable gate array), or a hardware accelerator. In an exemplary embodiment, the processor 305 may be configured to execute instructions stored in the memory device 310 or instructions otherwise accessible to the processor 305. As such, whether configured by hardware or software methods, or by a combination thereof, the processor 305 may represent an entity capable of performing operations according to embodiments of the present invention while configured accordingly. Thus, for example, when the processor 305 is embodied as an ASIC, FPGA or the like, the processor 305 may be specifically configured hardware for conducting the operations described herein. Alternatively, as another example, when the processor 305 is embodied as an executor of software instructions, the instructions may specifically configure the processor 305, which may otherwise be a general purpose processing element if not for the specific configuration provided by the instructions, to perform the algorithms and operations described herein. However, in some cases, the processor 305 may be a processor of a specific device (e.g., a mobile terminal) adapted for employing embodiments of the present invention by further configuration of the processor 305 by instructions for performing the algorithms and operations described herein.

The memory device 310 may be a computer-readable storage medium that may include volatile and/or non-volatile memory. For example, memory device 310 may include Random

Access Memory (RAM) including dynamic and/or static RAM, on-chip or off-chip cache memory, and/or the like. Further, memory device 310 may include non-volatile memory, which may be embedded and/or removable, and may include, for example, read-only memory, flash memory, magnetic storage devices (e.g., hard disks, floppy disk drives, magnetic tape, etc.), optical disc drives and/or media, non-volatile random access memory (NVRAM), and/or the like. Memory device 310 may include a cache area for temporary storage of data. In this regard, some or all of memory device 310 may be included within the processor 305.

Further, the memory device 310 may be configured to store information, data, applications, computer-readable program code instructions, or the like for enabling the processor 305 and the apparatus 300 to carry out various functions in accordance with exemplary embodiments of the present invention. For example, the memory device 310 could be configured to buffer input data for processing by the processor 305. Additionally, or alternatively, the memory device 310 may be configured to store instructions for execution by the processor 305.

The communication interface 315 may be any device or means embodied in either hardware, a computer program product, or a combination of hardware and a computer program product that is configured to receive and/or transmit data from/to a network and/or any other device or module in communication with the apparatus 300. Processor 305 may also be configured to facilitate communications via the communications interface by, for example, controlling hardware and/or software included within the communications interface 315. In this regard, the communication interface 315 may include, for example, one or more antennas, a transmitter, a receiver, a transceiver and/or supporting hardware, including a processor or software for enabling communications with network 320. Via the communication interface 315 and the network 320, the apparatus 300 may communicate with various other network entities in a peer-to-peer fashion or via indirect communications via a base station, access point, server, gateway, router, or the like.

The communications interface 315 may be configured to provide for communications in accordance with any wired or wireless communication standard. The communications interface 315 may be configured to support communications in multiple antenna environments, such as multiple input multiple output (MIMO) environments. Further, the communications interface 315 may be configured to support orthogonal frequency division multiplexed (OFDM) signaling. In some example embodiments, the communications interface 315 may be configured to communicate in accordance with various techniques, such as, second-generation (2G) wireless communication protocols IS-136 (time division multiple access (TDMA)), GSM (global system for mobile communication), IS-95 (code division multiple access (CDMA)), third-generation (3G) wireless communication protocols, such as Universal Mobile Telecommunications System (UMTS), CDMA2000, wideband CDMA (WCDMA) and time division-synchronous CDMA (TD-SCDMA), 3.9 generation (3.9G) wireless communication protocols, such as Evolved

Universal Terrestrial Radio Access Network (E-UTRAN), with fourth-generation (4G) wireless communication protocols, international mobile telecommunications advanced (IMT-Advanced) protocols, Long Term Evolution (LTE) protocols including LTE-advanced, or the like. Further, communications interface 315 may be configured to provide for communications in accordance with techniques such as, for example, radio frequency (RF), infrared (IrDA) or any of a number of different wireless networking techniques, including WLAN techniques such as IEEE 802.11 (e.g., 802.11a, 802.11b, 802.11g, 802.11n, etc.), wireless local area network (WLAN) protocols, world interoperability for microwave access (WiMAX) techniques such as IEEE 802.16, and/or wireless Personal Area Network (WPAN) techniques such as IEEE 802.15, BlueTooth (BT), low power versions of BT, ultra wideband (UWB), Wigbee and/or the like.

The user interface 325 may be in communication with the processor 305 to receive user input at the user interface 325 and/or to present output to a user as, for example, audible, visual, mechanical or other output indications. The user interface 325 may include, for example, a keyboard, a mouse, a joystick, a display (e.g., a touch screen display), a microphone, a speaker, or other input/output mechanisms. In some exemplary embodiments, the user interface 325 may be limited, or even eliminated.

The slot configuration manager 340 of apparatus 300 may be any means or device embodied in hardware, a computer program product, or a combination of hardware and a computer program product, such as processor 305 implementing instructions or a hardware configured processor 305, that is configured to carry out the functions of slot configuration manager 340 as described herein. In an exemplary embodiment, the processor 305 may include, or otherwise control the slot configuration manager 340. The slot configuration manager 340 may be embodied as one or more processors similar to, but separate from processor 305. In this regard, the slot configuration manager 340 may be in communication with processor 305. In various exemplary embodiments, the slot configuration manager 340 may reside on multiple apparatuses such that some or all of the functionality of the slot configuration manager 340 may be performed by a first apparatus, and the remainder of the functionality of the slot configuration manager 340 may be performed by one or more other apparatuses.

The slot configuration manager 340 may be configured to cause the apparatus 300 to receive or transmit backhauling or relaying communications in accordance with a baseline time slot pairing configuration as described above. The slot configuration manager 340 may be configured to conduct communications within a relaying or backhauling link between a donor node and a relay node. The communications of the relaying or backhauling link may be conducted in a TDD environment in accordance with identified UL-DL pairings. In this regard, at least one sub-frame time slot may be identified and treated as a MBSFN sub-frame timeslot to facilitate interference-free communications with respect to the relaying or backhauling link.

The slot configuration manager 340 may also be configured to analyze the communications received or otherwise identified as being attributed to the relaying or backhauling link. For example, the slot configuration manager 340 may be configured to analyze the communications to determine whether increased bandwidth, feedback, or re-transmission of data is needed in the relaying or backhauling link.

Further, the slot configuration manager 340 may be configured to increase, or in some example embodiments decrease, the capacity of the relaying or backhauling link. The capacity of the relaying or backhauling link may be increased based on the analysis by making at least one additional spare sub-frame available to the link or decreased by making at least one spare sub-frame unavailable to link. The spare sub-frame may be determined with respect to the baseline time slot pairing configuration used by the apparatus 300 as described above.

In some example embodiments, the slot configuration manager 340 may be configured to cause the apparatus 300 to transmit, re-transmit, or receive relaying or backhauling communications. In this regard, transmission, re-transmission, or receipt of relaying or backhauling communications may be conducted during an additional spare sub-frame.

FIG. 10 illustrates one or more flowcharts of a system, method, and computer program product according to exemplary embodiments of the invention. The flowcharts described by FIG. 10 may include, but need not require, one or more of the operations described with respect to FIG. 10. It will be understood that each block or operation of the flowcharts, and/or combinations of blocks or operations in the flowcharts, can be implemented by various means. Means for implementing the blocks or operations of the flowcharts, and/or combinations of the blocks or operations in the flowcharts may include hardware, and/or a computer program product including one or more computer program code instructions, program instructions, or executable computer-readable program code instructions. In one exemplary embodiment, one or more of the procedures described herein may be embodied by a computer program product including program code instructions. In this regard, the program code instructions may be stored by or on a memory device, such as memory device 310, of an apparatus, such as apparatus 300, and executed by a processor, such as the processor 305. As will be appreciated, any such program code instructions may be loaded onto a computer or other programmable apparatus (e.g., processor 305, memory device 310) to produce a machine, such that the instructions which execute on the computer or other programmable apparatus create means for implementing the functions specified in the flowcharts block(s) or operation(s). These program code instructions may also be stored in a computer-readable storage medium that can direct a computer, a processor, or other programmable apparatus to function in a particular manner, such that the instructions stored in the computer-readable storage medium produce an article of manufacture including means which implement the function specified in the flowcharts' block(s) or operation(s). The program code instructions may also be loaded onto a computer, processor, or other programmable apparatus to

cause a series of operations to be performed on or by the computer, processor, or other programmable apparatus to produce a computer-implemented process such that the instructions which execute on the computer, processor, or other programmable apparatus implement the functions specified in the flowcharts' block(s) or operation(s).

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

According to various example embodiments of the present invention, FIG. 10 depicts a flowchart of an example method for time slot configuration including operations 400 through 430. At 400, the example method includes receiving or transmitting relaying or backhauling communications in accordance with a baseline time slot pairing configuration. The communications may be conducted within a relaying or backhauling link. At 410, an analysis of communications received via the relaying or backhauling link may be conducted. At 420, the capacity of the relaying or backhauling link may be increased or reduced by adding or removing spare sub-frames from the relaying or backhauling link communications. Further, at 430, relaying or backhauling communications may be transmitted, re-transmitted, or received via the relaying or backhauling link during an added spare sub-frame.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Moreover, although the foregoing descriptions and the associated drawings describe exemplary embodiments in the context of certain exemplary combinations of elements and/or functions, it should be appreciated that different combinations of elements and/or functions may be provided by alternative embodiments without departing from the scope of the appended claims. In this regard, for example, different combinations of elements and/or functions other than those explicitly described above are also contemplated as may be set forth in some of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A method comprising:

causing establishment of a backhaul link between a donor node and a relay node; and

5 causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing.

2. The method of claim 1, wherein causing communications includes causing

10 communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing.

15 3. The method of claims 1 or 2, wherein causing communications includes causing communications using inband resources for the backhaul link in a time division duplexing network.

4. The method of any one of claims 1 through 3, wherein causing communications

20 includes causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration.

25 5. The method of any one of claims 1 through 4, further comprising:

modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings.

6. The method of claim 5, wherein modifying the baseline sub-frame uplink-

30 downlink pairings includes introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

35

7. An apparatus comprising at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, direct the apparatus at least to perform:

causing establishment of a backhaul link between a donor node and a relay node; and

causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing.

8. The apparatus of claim 7, wherein the apparatus directed to perform causing communications includes being directed to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing.

9. The apparatus of claims 7 or 8, wherein the apparatus directed to perform causing communications includes being directed to perform causing communications using inband resources for the backhaul link in a time division duplexing network.

10. The apparatus of any one of claims 7 through 9, wherein the apparatus directed to perform causing communications includes being directed to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration.

11. The apparatus of any one of claims 7 through 10, wherein the apparatus is further directed to perform:

modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings.

12. The apparatus of claim 11, wherein the apparatus directed to perform modifying the baseline sub-frame uplink-downlink pairings includes being directed to perform introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

13. The apparatus of any one of claims 7 through 12, wherein the apparatus comprises a base station; and wherein the apparatus further comprises communications circuitry and components for establishing the backhaul link.

14. The apparatus of claim 13, wherein the communications circuitry and components include at least one antenna.

15. A computer program product comprising at least one computer readable storage medium including computer program code, the computer program code configured to direct an apparatus to at least perform:

causing establishment of a backhaul link between a donor node and a relay node; and

causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing.

16. The computer program product of claim 15, wherein the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing.

17. The computer program product of claims 15 or 16, wherein the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications using inband resources for the backhaul link in a time division duplexing network.

18. The computer program product of any one of claims 15 through 17, wherein the computer program code configured to direct the apparatus to perform causing communications includes being configured to direct the apparatus to perform causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration.

19. The computer program product of any one of claims 15 through 18, wherein the computer program code is further configured to direct the apparatus to perform:

modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings.

20. The computer program product of claim 19, wherein the computer program code configured to direct the apparatus to perform modifying the baseline sub-frame uplink-downlink pairings includes being configured to direct the apparatus to perform introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

21. An apparatus comprising:

means for causing establishment of a backhaul link between a donor node and a relay node; and

means for causing communications via the backhaul link to be conducted in accordance with baseline sub-frame uplink-downlink pairings, wherein at least one sub-frame within the baseline sub-frame uplink-downlink pairings is implemented as a multicast to downlink sub-frame pairing.

22. The apparatus of claim 21, wherein the means for causing communications includes means for causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is a multicast multicast/broadcast over single frequency network sub-frame to downlink pairing.

23. The apparatus of claims 21 or 22, wherein the means for causing communications includes means for causing communications using inband resources for the backhaul link in a time division duplexing network.

24. The apparatus of any one of claims 21 through 23, wherein the means for causing communications includes means for causing communications to be conducted in accordance with the baseline sub-frame uplink-downlink pairings, wherein a time slot for the at least one sub-frame implemented as the multicast to downlink sub-frame pairing is based on an implemented uplink-downlink time slot configuration.

25. The apparatus of any one of claims 21 through 24, further comprising:

means for modifying a capacity of the backhaul link based on a throughput analysis by modifying the baseline sub-frame uplink-downlink pairings.

26. The apparatus of claim 25, wherein the means for modifying the baseline sub-frame uplink-downlink pairings includes means for introducing an additional multicast to downlink sub-frame pairing as a spare sub-frame or removing a multicast to downlink sub-frame pairing.

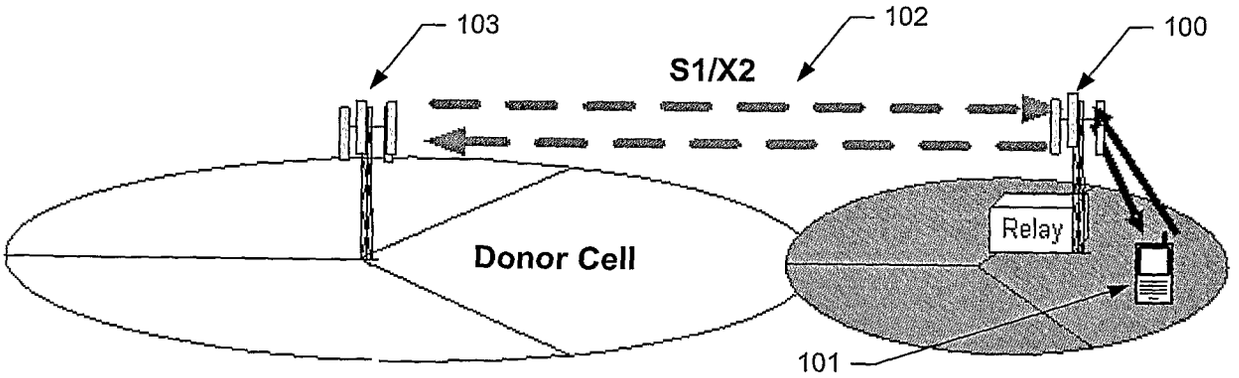

FIG. 1A

RN/DN view	DN->UE/RN	RN->UE	UE/RN->DN	UE->RN
UE view	DN->UE	RN->UE	UE->DN	EU->RN
Subframe	i	i+1	i+2	i+3

DN = donor node

FIG. 1B

UL-DL Configuration	Sub-frame Number									
	0	1	2	3	4	5	6	7	8	9
0	D	S	U	U	U	D	S	U	U	U
1	D	S	U	U	D	D	S	U	U	D
2	D	S	U	D	D	D	S	U	D	D
3	D	S	U	U	U	D	D	D	D	D
4	D	S	U	U	D	D	D	D	D	D
5	D	S	U	D	D	D	D	D	D	D
6	D	S	U	U	U	D	S	U	U	D

FIG. 1C

TTI	1	2	3	4	5	6	7	8	9	10
Subframe	0	1	2	3	4	5	6	7	8	9
donor node	D	S	U	U	**D**	D	S	U	U	**M**
CONFIGURATION 1					→					←
RN	D	S	U	U	**M**	D	S	U	U	**D**

FIG. 2

TDD UL/DL Configurations	Baseline HARQ configuration for backhaul link			
	Sub-frame pairing	HARQ Process number	HARQ RTT (ms)	Feedback delay (ms)
0	N.A.			
1	Sub-frame 4+9	1	10	5
2	Sub-frame 3+8 Or Sub-frame 4+9	1	10	5
3	Sub-frame 8+9	1	20	11/9
4	Sub-frame 4+9	1	10	5
5	Sub-frame 3+8 or Sub-frame 4+9	1	10	5
6	Sub-frame 9	1	20	10

FIG. 3

TDD UL/DL Configurations	Baseline Configurations	Spare Sub-frame
2	Sub-frame 3+8	Sub-frame #4, #9
	Sub-frame 4+9	Sub-frame #3, #8
3	Sub-frame 8+9	Sub-frame #7
4	Sub-frame 4+9	Sub-frame #7, #8
5	Sub-frame 3+8	Sub-frame #4, #7, #9
	Sub-frame 4+9	Sub-frame #3, #7, #8

FIG. 4

TTI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Subframe	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
donor node	D	S	U	**M**	D	D	S	U	**D**	**D**	D	S	U	**M**	D	D	S	U	**D**	**D**
CONFIGURATION 2				↑					↓	⇣				↑					↓	⇣
RN	D	S	U	**D**	**D**	**D**	**S**	**U**	**M**	**M**	**D**	**S**	**U**	**D**	D	D	S	U	**M**	**M**

FIG. 5

TTI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Subframe	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
donor node	D	S	U	**D**	D	D	D	D	**M**	D	D	S	U	**D**	D	D	D	D	**M**
CONFIGURATION 5				↓ ⇣					↑ ⇡					↓ ⇣					↑ ⇡
RN	D	S	U	**M**	D	D	D	D	**D**	D	D	S	U	**M**	D	D	D	D	**D**

↓ **Donor node -> RN transmission**

↑ **RN -> Donor Node transmission**

⇣ **DL feedback for previous UL sub-frame**

⇡ **UL feedback for previous DL sub-frame**

FIG. 6

TTI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1	2	3	4	5	6	7	8	9	10
Subframe	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
donor node	D	S	U	U	**D**	D	D	**D**	D	**M**	D	S	U	U	**D**	D	D	D	D	**M**	D	S	U	U	**D**	D	D	**D**	D	**M**
CONFIGURATION 4					↓			↓		↑					↓					↑ ↑ ⇡					↓			↓ ↓ ⇡		↑
RN	D	S	U	U	**M**	D	D	**M**	D	**D**	D	S	U	U	**M**	D	D	M	D	**D**	D	S	U	U	**M**	D	D	**M**	D	**D**

↓ **Donor node -> RN transmission**

↑ **RN -> Donor Node transmission**

⇡ **DL re-tranmission for previous sub-frame #7**

⇡ **UL feedback for DL sub-frame #7**

FIG. 7

TDD UL/DL Configurations	Baseline HARQ configuration for backhaul link				Spare backhaul link sub-frame	
	Sub-frame pairing	HARQ Process number	HARQ RTT (ms)	Feedback delay (ms)	Spare Sub-frame	How to design HARQ
0	N.A.				N.A.	
1	Sub-frame 4+9	1	10	5	N.A	N.A.
2	Sub-frame 3+8 Or Sub-frame 4+9	1	10	5	Sub-frame 4+9 Or Sub-frame 3+8	•If spare sub-frame is enabled, then the feedback of spare sub-frame should reside in the first available backhaul link sub-frame after 3ms. The retransmission is also in this spare sub-frame. With this rule, it s easy to design HARQ process • Maximal number of HARQ process = number of available sub-frame in that dirrection
3	Sub-frame 8+9	1	20	11/9	Sub-frame 7	
4	Sub-frame 4+9	1	10	5	Sub-frame 7 and 8	
5	Sub-frame 3+8 or Sub-frame 4+9	1	10	5	Sub-frame 7 &sub-frame 4+9; Or sub-frame7 *sub-frame3+8	
6	Sub-frame 9	1	20	10	N.A.	

FIG. 8

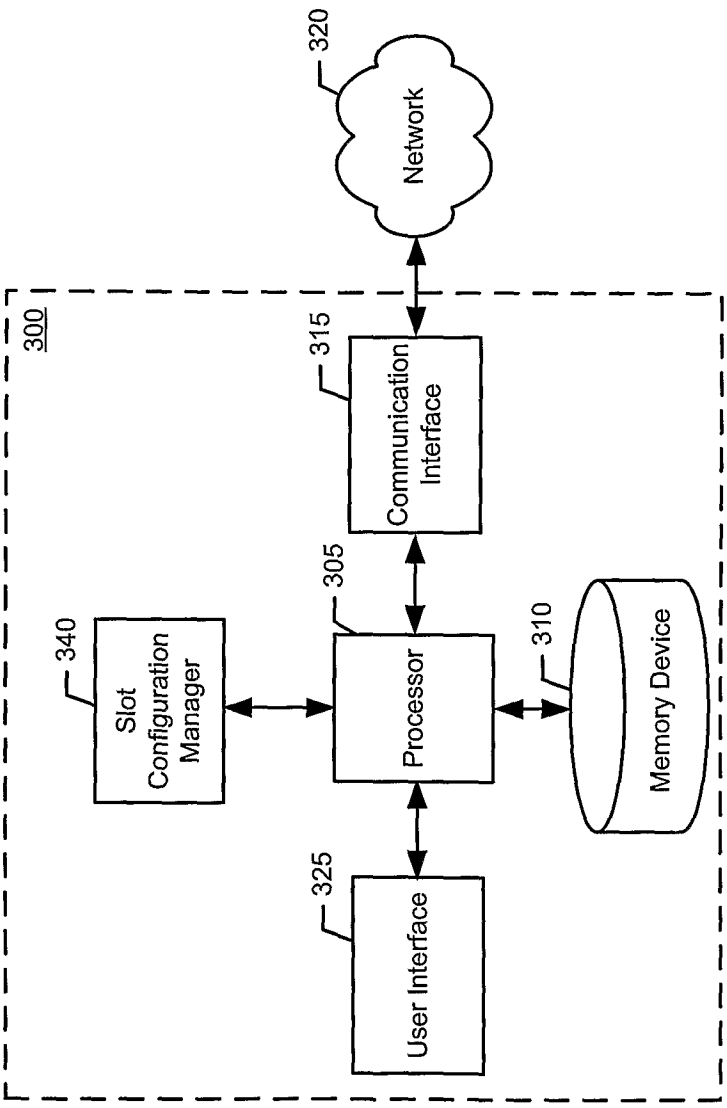
300
340
Slot Configuration Manager
305
Processor
315
Communication Interface
320
Network
310
Memory Device
325
User Interface

FIG. 9

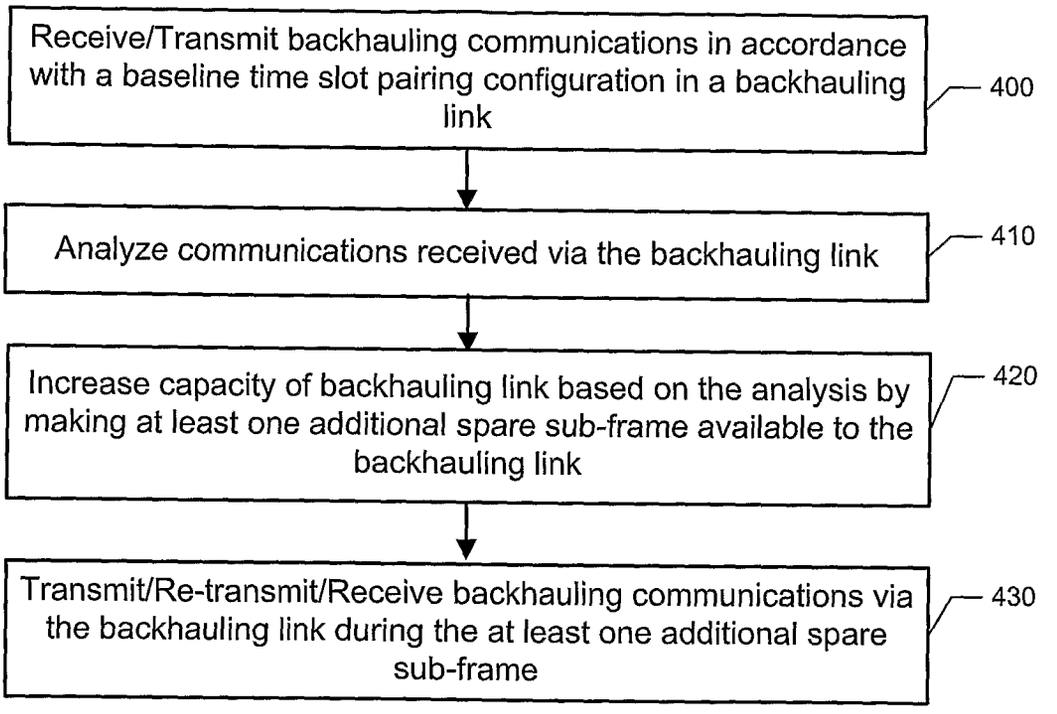
Receive/Transmit backhauling communications in accordance with a baseline time slot pairing configuration in a backhauling link
400
Analyze communications received via the backhauling link
410
Increase capacity of backhauling link based on the analysis by making at least one additional spare sub-frame available to the backhauling link
420
Transmit/Re-transmit/Receive backhauling communications via the backhauling link during the at least one additional spare sub-frame
430

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2010/000286

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see 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: H04B, H04L, H04W

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ, INSPEC, 3GPP

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP TSG RAN WG1 Meeting #56 R1-090734, Athens, Greece, February 9-13, 2009, Nokia, Nokia Siemens Networks,"Considerations on TDD Relay"; Chapters 1,2, 2.1, figure 1 --	1-26
X	TSG-RAN WG1 #55 R1-084357, Prague, Czech Republic, November 10 - 14, 2008, Ericsson, "Efficient support of relays through MBSFN subframes", Agenda Item: 6.1; Chapters 1,2, 2.2, figure 3 --	1-26

[X] 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
8 June 2010	09-06-2010
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Markus Stålö / MRo Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	3GPP TSG RAN WG1 Meeting #56, R1-090827, Athens, Greece, February 9-13, 2009, Agenda Item: 12.5, Huawei, "Summary and proposal of relay frame structure"; Chapter 2.1, figure 1 --	1-26
X	3GPP TSG RAN WG1 Meeting #56, R1-090665, Athens, Greece, February 9th - 13th, 2009, Agenda item: 12.5, LG Electronics, "UL subframe stealing for in-band relaying in TDD mode"; Chapter 3, figure 3 --	1-26
A	3GPP TSG RAN WG1 Meeting #56, R1-090664, Athens, Greece, February 9th - 13th, 2009, Agenda item: 12.5, LG Electronics, "Comparison of in-band relaying methods in FDD mode"; Chapter 2, figure 3 --	1-26
P,X	3GPP TSG-RAN WG1 #56bis, R1-091404, Seoul, Korea, 23-27 Mar, 2009, Vodafone, "Relay backhauling via MBSFN Sub Frame for TDD LTE system", Agenda Item: 15.3; Chapter 3 --	

International patent classification (IPC)

H04W 16/26 (2009.01)
H04B 7/15 (2006.01)