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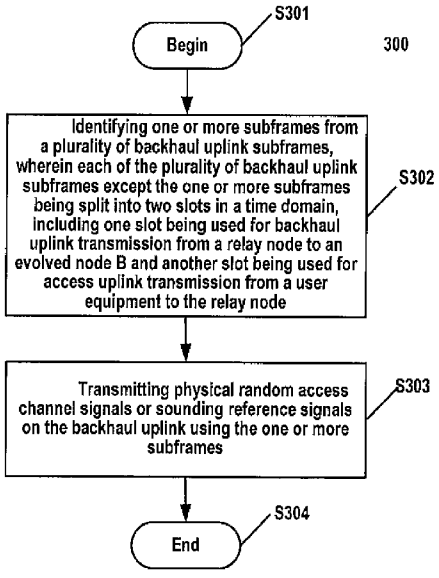

Fig. 3

(57) Abstract: Provided are methods, apparatuses and computer program products for transmitting physical random access channel signals or sounding reference signal on the backhaul uplink. A method comprises identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes. Another method comprises transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe. A further method comprises scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe. Thus, backhaul scheduling delay may be shortened and backhaul scheduling gain may be increased with guaranteed backhaul sounding reference signal transmission.

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TRANSMITTING PHYSICAL RANDOM ACCESS CHANNEL AND SOUNDING REFERENCE SIGNAL IN TDD RELAY SYSTEM

FIELD OF THE INVENTION

[0001] Embodiments of the present invention generally relate to wireless cellular communication. More particularly, embodiments of the present invention relate to methods, apparatuses and computer program products for transmitting physical random access channel signals and sounding reference signals in a TDD (Time Division Duplexing) relay system.

BACKGROUND OF THE INVENTION

[0002] Various abbreviations that appear in the specification and/or in the drawing figures are defined as below:

3GPP	Third Generation Partnership Project
LTE	Long Term Evolution
LTE R8	LTE Release 8
LTE-A	LTE Advanced
UMTS	Universal Mobile Telecommunications System
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
RAN	Radio Access Net
BS	Base Station
RRM	Radio Resource Management
e-NB	Evolved or Enhanced Node B
DeNB	Donor e-NB
RN	Relay Node
UE	User Equipment
RN-UE	Relay attached UE
TDD	Time Division Duplexing
FDD	Frequency Division Duplexing
TDM	Time Division Multiplexing

ACK	Acknowledgment
NACK	Non-Acknowledgment
SRS	Sounding Reference Signal
UL	Uplink
DL	Downlink
SR	Scheduling Request
PRB	Physical Resource Block
OFDM	Orthogonal Frequency Division Multiplex
PRACH	Physical Random Access Channel
SC-FDMA	Single Carrier-Frequency Division Multiple Access
PRB	Physical Resource Block

[0003] Relay is one of promising approaches to extend cell coverage and enhance cell capacity with a low cost for LTE-A system. There are many kinds of relay ways which might be applicable to different wireless communication scenarios. In 3GPP RAN1#56 meetings, "type 1" RN has been selected as baseline supported relay type in LTE-Advanced at least. "Type 1" relay is an inband relay which will use the same frequency band for backhaul link between the RNs and a BS (also called as Node B or e-NB) and access link between the RN and UEs, and which is under the control of cells of its own. The details regarding "type 1" RN can be found in R1-091112, entitled "Text proposal on type 1 relaying," Ericsson, and which is incorporated herein by reference in its entirety. In such a "type 1" relay system, a unique physical layer cell identity is provided in each of the cells and the same RRM mechanisms and protocol stacks are available. From the UE point of view, there is no difference between the cells controlled by the RN and cells controlled by a "normal" e-NB. Additionally, the cells controlled by the RN should also support communications of LTE Rel-8 UEs, thus a mandatory backward compatibility was required. Moreover, for "Type 1" relay, access link and backhaul link transmissions are time multiplexed, which means that a RN cannot communicate with RN-UEs and an e-NB simultaneously.

[0004] In a TDD relay system, the TDM feature of access link and backhaul link transmissions for "Type 1" relay could result in uplink feedback missing problems in which the RN is switched to a transmit backhaul mode at the critical subframe and

thus no uplink between the UEs and the RN is available for receipt of feedback (such as ACK/NACK feedback). An uplink splitting scheme has been proposed for solving this problem in an efficient manner. The details regarding the uplink splitting scheme can be found in R1-091767, entitled "Improved Access-backhaul Partition Scheme for TDD Relay," Nokia Corporation and Nokia Siemens Networks OY, and which is incorporated herein by reference in its entirety. In this scheme, one uplink subframe has been split into two slots in a time domain, wherein one slot is used for backhaul uplink transmission from the RN to the BS and the other slot is used for access uplink transmission from the UE to the RN (e.g., used to obtain feedbacks on an access link). This special subframe structure is capable of performing backhaul transmission and receiving uplink feedback in one subframe, thereby eliminating the above-discussed uplink feedback missing problem in a TDD relay system.

[0005] However, the foregoing special subframe structure as used in the uplink splitting scheme may cause some potential impacts on PRACH transmission and SRS transmission on a backhaul link. As is well known to those skilled in the art, PRACH on a backhaul link has been mainly used for scheduling request in an uplink when there has no uplink feedback channel configured for a backhaul link. In addition, SRS has been used for frequency domain scheduling for a backhaul uplink. The impact of the foregoing special subframe structure as used in the uplink splitting scheme on PRACH transmission and SRS transmission on a backhaul link are described in detail as below.

[0006] In LTE R8, there are five configurations for random access preamble formats (for more details regarding the preamble formats, see 3GPP Specification 36.211 V900, entitled "Physical Channels and Modulation"), which are exemplarily illustrated as below:

Preamble formats(#)	T_{CP}	T_{SEQ}
0	0.1ms	0.8ms
1	0.68ms	0.8ms
2	0.2ms	1.6ms
3	0.68ms	1.6ms
4	0.014ms	0.13ms

[0007] In the above table, T_{CP} is the time length of a cyclic prefix for a random access preamble and T_{SEQ} is the time length of a preamble sequence. For

conciseness, another item of the time length, i.e., T_{GP} (time of guide period), is omitted in the above table. Assuming that the time length of T_{GP} is 0.2ms, the preamble formats #0-#3 each have a time length (T_{CP}+T_{SEQ}+ T_{GP}) longer than 1ms and only preamble format #4 may have a time length shorter than 1ms. As noted above, in the uplink splitting scheme, the subframe (approximately 1ms in the time length) has been split into two slots and thus the slot for backhaul uplink transmission (approximately 0.5ms in the time length) cannot be used for transmitting a random access preamble sequence which has a time length longer than 0.5ms. In other words, the random access preamble sequences in the preamble formats #0-#3 cannot be transmitted in the uplink splitting scheme in LTE Rel 8. Preamble format #4 has a time length shorter than 0.5ms and it seems usable in the uplink splitting scheme. However, in practice, preamble format #4 can only be used for very small cells (such as microcells or micro-microcells) and thus has very limited use scenarios. Consequently, these RNs could not request backhaul uplink resource on a backhaul link.

[0008] Furthermore, in LTE Rel 8, there are total 14 symbols (numbered from #0 to #13) in one subframe and the SRS has always been transmitted in the last symbol in one subframe, i.e., only in symbol #13. However, in the uplink splitting scheme, some of the backhaul uplink transmission implemented by the RNs is in the first half subframe, i.e., symbol #0 to symbol #6, then there is no chance of transmitting the SRS on the backhaul uplink for those RNs. Thereby, the frequency scheduling gain on the backhaul uplink for those RNs is reduced and accordingly the backhaul transmission efficiency is decreased.

SUMMARY OF THE INVENTION

[0009] In view of the forgoing problems in the uplink splitting scheme with respect to PRACH signals and SRS transmission, there is a need in the art to provide methods and apparatuses for transmitting PRACH signals or SRS on a backhaul uplink in the uplink splitting scheme.

[0010] One embodiment of the present invention provides a method. The method comprises identifying one or more subframes from a plurality of backhaul uplink subframes. Each of the plurality of backhaul uplink subframes except the one

or more subframes has been split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node. The method also comprises transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

[0011] In one embodiment, the identifying the one or more subframes from the plurality of backhaul uplink subframes is based on signaling information received from the evolved node B. Additionally, the signaling information may comprise information for specifying a periodicity or location of the one or more subframes among backhaul uplink subframes.

[0012] Another embodiment of the present invention provides a method. The method comprises transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe. The backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

[0013] In one embodiment, the transmitting the sounding reference signal in the last symbol in the first slot of the backhaul uplink subframe is scheduled by the evolved node B using signaling information.

[0014] An additional embodiment of the present invention provides a method. The method comprises scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe. Each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to an evolved node B.

[0015] In one embodiment, the scheduling the transmitting by the relay node the sounding reference signal in the backhaul uplink subframe is based upon a timer in the evolved Node B. The method further comprises: upon expiration of a predetermined time period, forcing the relay node to transmit the sounding reference in a second slot of the backhaul uplink subframe; and initiating the timer.

[0016] A further embodiment of the present invention provides an apparatus.

The apparatus comprises means for identifying one or more subframes from a plurality of backhaul uplink subframes. Each of the plurality of backhaul uplink subframes except the one or more subframes has been split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node. The apparatus further comprises means for transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes. In one embodiment, the apparatus comprises the relay node.

[0017] In one embodiment, the means for identifying the one or more subframes from the plurality of backhaul uplink subframes is based on signaling information received from the evolved node B.

[0018] In another embodiment, the signaling information comprises information for specifying a periodicity or location of the one or more subframes among backhaul uplink subframes.

[0019] Another embodiment of the present invention provides an apparatus. The apparatus comprises means for transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe. The backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node. In one embodiment, the apparatus comprises the relay node.

[0020] In an additional embodiment, the means for transmitting the sounding reference signal in the last symbol in the first slot of the backhaul uplink subframe is scheduled by the evolved node B using signaling information.

[0021] One of embodiments of the present invention provides an apparatus. The apparatus comprises means for scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe. Each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to an evolved node B. In one embodiment, the apparatus comprises the evolved Node B.

[0022] In a further embodiment, the means for scheduling the transmitting by the relay node the sounding reference signal in the backhaul uplink subframe is based upon a timer in the evolved Node B and the apparatus further comprises: means for forcing the relay node to transmit the sounding reference in a second slot of the backhaul uplink subframe upon expiration of a predetermined time period; and means for initiating the timer.

[0023] One embodiment of the present invention provides an apparatus. The apparatus comprises at least one processor and at least one memory including compute program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least perform: identify one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and transmit physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes. In one embodiment, the apparatus comprises the relay node.

[0024] Another embodiment of the present invention provides an apparatus. The apparatus comprises at least one processor and at least one memory including compute program code, the at least one memory and the computer program code configured to, with the least one processor, cause the apparatus to at least perform: transmit a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe, wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node. In one embodiment, the apparatus comprises the relay node.

[0025] An additional embodiment of the present invention provides an apparatus. The apparatus comprises at least one processor and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to at least

perform: schedule transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to the evolved node B. In one embodiment, the apparatus comprises the evolved Node B.

[0026] One embodiment of the present invention provides a computer program product. The computer program product comprises at least one computer readable storage medium having a computer readable program code portion stored thereon. The computer readable program code portion comprises program code instructions for identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node. The computer readable program code portion further comprises program code instructions for transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

[0027] Another embodiment of the present invention provides a computer program product. The computer program product comprises at least one computer readable storage medium having a computer readable program code portion stored thereon. The computer readable program code portion comprises program code instructions for transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe, wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

[0028] A further embodiment of the present invention provides a computer program product. The computer program product comprises at least one computer readable storage medium having a computer readable program code portion stored thereon. The computer readable program code portion comprises program code instructions for scheduling transmitting, by a relay node, a sounding reference signal in

a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to the evolved node B.

[0029] With certain embodiments of the present invention, RNs may request uplink resources on a backhaul link by transmitting PRACH signals. Further, backhaul scheduling delay may be shortened and backhaul scheduling gain may be increased with guaranteed backhaul SRS transmission.

[0030] Other features and advantages of the embodiments of the present invention will also be understood from the following description of specific embodiments when read in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] The embodiments of the invention are presented in the sense of examples and their advantages are explained in greater detail below with reference to the accompanying drawings, in which:

[0032] Fig. 1 exemplarily illustrates a simplified system level diagram of a wireless communication system that provides an environment and structure for application of the principles of the present invention;

[0033] Fig. 2 exemplarily illustrates a block diagram of an embodiment of a wireless communication device and a network element;

[0034] Fig. 3 is a flow chart illustrating a method for transmitting PRACH signals or SRS on a backhaul uplink according to an embodiment of the present invention;

[0035] Fig. 4 exemplarily illustrates a PRACH subframe sequence in one embodiment as illustrated in Fig. 3;

[0036] Fig. 5 exemplarily illustrates a SRS subframe sequence in one embodiment as illustrated in Fig. 3;

[0037] Fig. 6 is a flow chart illustrating a method for transmitting a SRS in a new format on the backhaul uplink transmission according to an embodiment of the

present invention;

[0038] Fig. 7 exemplarily illustrates a subframe structure of the new SRS format as used in one embodiment as illustrated in Fig. 6; and

[0039] Fig. 8 is a flow chart illustrating a method for scheduling transmission of SRSin a further embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0040] Embodiments of the present invention will be described in detail as below.

[0041] In one embodiment of the present invention, one or more subframes, without being split, among a plurality of backhaul subframes are defined for being exclusively used for PRACH signals or SRS transmission on a backhaul uplink. In another embodiment of the present invention, a new SRS format of the backhaul subframe is defined for SRS transmission. For example, the last symbol in the first half subframe may be defined for the SRS transmission. In a further embodiment of the present invention, transmitting the SRS by the RN may be forced by an e-NB. To this end, a SRS timer may be defined with respect to each RN; the eNB may force a RN to transmit SRS in the last symbol of the second slot.

[0042] Fig. 1 exemplarily illustrates a simplified system level diagram of a wireless communication system 1 that provides an environment and structure for application of the principles of the present invention. In Fig.1, an e-NB 11 is coupled to a RN 13 by a link 16 (i.e., backhaul link). The RN 13 is depicted in communication with two UEs labeled 15 over links 17 (i.e., access links). Double-headed arrows depicted are used to indicate that communications between e-NB and RN and between RN and UEs are bidirectional. The UEs are registered with the e-NB in such a manner that the presence of the RN is transparent to the UEs, that is, the messages sent and received by these UEs operate in the same manner as if they were directly connected to the e-NB.

[0043] Fig. 2 illustrates in a block diagram the blocks of a communication element 21 coupled to a telecommunication network by a network control element 29. The communication element 21 may represent, without limitation, an apparatus

including an e-NB, a UE such as a terminal or mobile station, a RN, a network control element, or the like. The communication element 21 includes, at least, a processor 25, a memory 27 that stores programs and data of a temporary or more permanent nature, an antenna, and a radio frequency transceiver 23 coupled to the antenna and the processor 25 for bidirectional wireless communication. Other components/functions may also be provided. The communication element may provide point-to-point and/or point-to-multipoint communication services.

[0044] The communication element 21, such as an e-NB in a cellular network, may be coupled to a communication network element 29, such as a network control element of a public switched telecommunication network (PSTN). The network control element may, in turn, be formed with a processor, a memory, and other electronic elements (not shown). Access to the PSTN may be provided using fiber optic, coaxial, twisted pair, microwave communication, or similar communication links coupled to an appropriate link-terminating element. A communication element 21 formed as a UE is generally a self-contained device intended to be carried by an end user and communicating over an air interface to other communication elements in the network.

[0045] The processor 25 in the communication element, which may be implemented with one or a plurality of processing devices, performs functions associated with its operation including, without limitation, encoding and decoding of individual bits forming a communication message, formatting of information, and overall control of the communication element, including processes related to management of resources. Exemplary functions related to management of resources include, without limitation, hardware installation, traffic management, performance data analysis, tracking of end users and mobile stations, configuration management, end user administration, management of the mobile station, management of tariffs, subscriptions, and billing, and the like. The execution of all or portions of particular functions or processes related to management of resources may be performed in equipment separate from and/or coupled to the communication element, with the results of such functions or processes communicated for execution to the communication element. The processor 25 of the communication element may be of any type suitable to the local application environment, and may include one or more of general-purpose computers,

special-purpose computers, microprocessors, digital signal processors (DSPs), and processors based on a multi-core processor architecture, as non-limiting examples.

[0046] The transceiver 23 of the communication element 21 modulates information onto a carrier waveform for transmission by the communication element via the antenna to another communication element. The transceiver demodulates information received via the antenna for further processing by other communication elements.

[0047] The memory 27 of the communication element 21, as introduced above, may be of any type suitable to the local application environment, and may be implemented using any suitable volatile or nonvolatile data storage technology, such as a semiconductor-based memory device, a magnetic memory device and system, an optical memory device and system, fixed memory, and removable memory. The programs stored in the memory may include program instructions that, when executed by an associated processor, enable the communication element to perform tasks as described herein. Exemplary embodiments of the system, subsystems, and modules as described herein may be implemented, at least in part, by computer software executable by processors of, for instance, the mobile station and the base station, or by hardware, or by combinations thereof. Other programming may be used such as firmware and/or state machines. As it will become more apparent, systems, subsystems and modules may be embodied in the communication element 21 as illustrated and described above.

[0048] Fig. 3 is a flow chart illustrating a method for transmitting PRACH signals or SRS on a backhaul uplink according to an embodiment of the present invention. As illustrated in Fig. 3, the method 300 begins at step S301 and identifies one or more subframes from a plurality of backhaul uplink subframes at step S302. Each of the plurality of backhaul uplink subframes except the one or more subframes has been split into two slots in a time domain. The two slots include one slot being used for backhaul uplink transmission from a relay node to an e-NB and another slot being used for access uplink transmission from a UE to the RN. In one embodiment, the identifying the one or more subframes from the plurality of backhaul uplink subframes may be based on signaling information received from the e-NB. In another embodiment, the signaling information may be conveyed in RRC signaling from the e-NB. Furthermore, the signaling information may comprise information for

specifying a periodicity or location of the one or more subframes among backhaul uplink subframes. At step S303, the method 300 transmits PRACH signals or SRS on the backhaul uplink using the one or more subframes as identified in step S302. Finally, the method 300 ends at step S304.

[0049] From the above method 300, it can be seen that the one or more subframes as identified at step S302 is not split into two slots, that is, the uplink splitting scheme is disabled in the identified one or more subframes. These subframes will then be exclusively or dedicatedly used for transmitting PRACH signals and/or SRS on the backhaul uplink. Because the whole subframe is left for transmitting PRACH or SRS, the random access preamble formats in LTE Rel 8, e.g., preamble format #0, could be reused on these subframes.

[0050] Fig. 4 exemplarily illustrates a PRACH subframe sequence in one embodiment as illustrated in Fig. 3. In Fig. 4, a plurality of subframes 1-30 are illustrated as boxes filled with different patterns (e.g., straight lines or oblique lines) to represent different communication contents. Subframes 1 and 30 filled with oblique lines are PRACH backhaul uplink subframes, which may be identified by the method 300 in step S302 as described above. Subframes 10 and 20 filled with straight lines are the backhaul uplink subframes that have been split into two slots using the uplink splitting scheme as described previously. The time period from PRACH backhaul uplink subframe 1 to PRACH backhaul uplink subframe 30 represents the periodicity of the PRACH backhaul uplink subframes.

[0051] For a backhaul link, PRACH transmission is mainly used for requesting uplink resources when SR resources are released due to lack of uplink scheduling during a period. Because all the RN-UE's data are transmitted over the backhaul link between the RN and the eNB by the RN, the backhaul link is much more active than an access link, which means that uplink scheduling is relatively frequent and using the PRACH to request uplink resource is relatively rare. Thus the periodicity of PRACH backhaul subframe could be longer and less frequent. The periodicity of PRACH backhaul subframes, as illustrated in Fig. 4 by double-headed arrows, could be on the order of hundreds of milliseconds or even longer (e.g., several seconds), and thus the impacts on the gain as obtained from the uplink splitting scheme will be minimized because only a small amount of subframes will be exclusively used for transmitting

PRACH signals.

[0052] It should be understood that the positions or periodicity of the PRACH backhaul uplink subframes (in other words, the number of each PRACH backhaul uplink subframe) as illustrated in Fig. 4 are only illustrative and the positions or periodicity of the PRACH backhaul uplink subframes can be specified by the signaling information conveyed from an E-NB via RRC signaling. That is, the positions or periodicity of the PRACH backhaul uplink subframes are configured in a semi-static way.

[0053] Fig. 5 exemplarily illustrates a SRS subframe sequence in one embodiment as illustrated in Fig. 3. The SRS subframe sequence in Fig. 5 may be similar to the PRACH subframe sequence as illustrated in Fig. 4 except that PRACH backhaul uplink subframes are replaced with SRS backhaul uplink subframes in the subframe sequence. Hence, among other things, the descriptive illustration with regard to the PRACH subframe sequence is also applicable to the SRS subframe sequence in Fig. 5. In addition, because the location of "Type 1" relay is fixed, the channel quality for backhaul links may change slowly and the periodicity of SRS backhaul uplink subframes could also be on the order of hundreds of milliseconds or even longer (e.g., several seconds), which will also minimize the impacts on the gain as obtained from the uplink splitting scheme.

[0054] Fig. 6 is a flow chart illustrating a method 600 for transmitting a SRS in a new format on the backhaul uplink transmission according to an embodiment of the present invention. As illustrated in Fig. 6, the method 600 begins at step S601 and transmits a SRS in the last symbol of a first slot of a backhaul uplink subframe at step S602. The backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain. The first slot is used for backhaul uplink transmission from a RN to an e-NB and the second slot is used for access uplink transmission from a UE to the RN. Unlike transmitting the SRS in the last symbol of the whole subframe, the new format of transmitting the SRS in the last symbol of the first slot of the backhaul uplink subframe may make a first half subframe also available for SRS backhaul uplink transmission. For example, with respect to the whole subframe consisting of 14 symbols from symbol #0 to symbol #13, symbol #6, i.e., the last symbol in the first half subframe (symbol #0 to symbol #6, forming the first slot), may

also be used to transmit the SRS as may the symbol #13. In one embodiment, the transmitting the SRS in the last symbol of the first slot of the backhaul uplink subframe is scheduled by the e-NB using signaling information (e.g., RRC signaling). Finally, the method ends at step S603.

[0055] Fig. 7 exemplarily illustrates a subframe structure of the new SRS format in one embodiment as illustrated in Fig. 6. As illustrated in Fig. 7, a whole subframe 70 may comprise 14 SC-FDMA symbols; each SC-FDMA symbol is represented by one of columns 0-13. Columns 0-6 may constitute a first slot (e.g., the first half subframe) and columns 7-13 may constitute a second slot (e.g., the second half subframe). In the first slot and the second slot, the blocks covered by the straight lines represent data region 71 for access uplink transmission from the UEs to RN and data region 72 for backhaul uplink transmission from the RN to the eNB, respectively. Column 13, i.e., the last symbol #13 in the subframe 70, has always been used for SRS transmission on the backhaul uplink in LET Rel 8. To avoid the situation in which the first slot is used for access uplink transmission and thus there is no symbol for SRS transmission, in one embodiment of the present invention, the last symbol of the first slot, i.e., symbol #6, as indicated by the arrow 73, is also defined as a location for SRS transmission. As such, the configuration of SRS transmission for these two half subframes may be the same and thus the RN may be configured with SRS transmission in any subframe. Additionally, the RN may reuse LTE R8 SRS configuration signaling.

[0056] To guarantee that the RN may transmit the SRS to the eNB in the second slot, in one embodiment of the present invention, a provided method comprises scheduling transmitting, by a RN, a SRS in a backhaul uplink subframe. In such an embodiment, each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a UE to the RN and another slot being used for backhaul uplink transmission from the RN to the eNB. In addition, such scheduling may be based upon a timer, which may also be called a SRS timer, e.g., located in the eNB. Upon expiration of a predetermined time period at the timer, the RN may be forced to transmit SRS in a second slot, e.g., by such scheduling, and the timer may be reinitiated. To further illustrate the method regarding the timer, reference is now made to Fig. 8.

[0057] Fig. 8 is a flow chart illustrating a method for scheduling transmission of SRS in a further embodiment of the present invention. As illustrated in Fig. 8, the method 800 begins at step S801 and initiates (e.g., set to zero) a SRS timer at step S802. At step S803, the method 800 schedules backhaul uplink transmissions from the RN to an eNB. At step S804, the method 800 decides whether the SRS has been transmitted by the RN. If the result in step S804 is "Yes," the method 800 returns to step S802. Then at step S802, the SRS timer is initiated again. If the result in step S804 is "No," then the method 800 proceeds to step S805. At step S805, the method 800 increments the SRS timer, e.g., by step of ONE. The method 800 then proceeds to step S806. At step S806, the method 800 decides whether the SRS timer is expired.

[0058] If the result in step S806 is "Yes," the method 800 proceeds to step S807. At step S807, the method 800 forces (e.g., by scheduling) the RN to transmit the SRS in the last symbol of a second slot on the backhaul uplink. Then the method 800 may proceed to step S808 where the method 800 may end for once SRS transmission. Because the backhaul uplink transmission from the RN to the eNB generally lasts a very long time, subsequent to step S807, the method 800 may also return to step S802, where the SRS timer is initiated again to begin a next round of flow such that the SRS can be received all the time.

[0059] The exemplary embodiments as described above are directed to an LTE or LTE-A 3GPP communications system with relay nodes using an uplink splitting scheme in TDD configuration. However, the exemplary embodiments are not limited to this illustrative, non-limiting example application and the use of the exemplary embodiments in other communications systems to provide rules for the advantageous transmitting of PRACH or SRS subframes in a TDD communication system with RNs using the uplink splitting scheme is envisioned as part of the present invention and within the scope of any claims attached.

[0060] In addition, exemplary embodiments of the present invention have been described above with reference to block diagrams and flowchart illustrations of methods, apparatuses (i.e., systems). It should be understood that each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations, respectively, can be implemented by various means including computer program instructions. These computer program instructions

may be loaded onto a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks.

[0061] The foregoing computer program instructions can be, for example, sub-routines and/or functions. A computer program product in one embodiment of the invention comprises at least one computer readable storage medium, on which the foregoing computer program instructions are stored. The computer readable storage medium can be, for example, an optical compact disk or an electronic memory device like a RAM (random access memory) or a ROM (read only memory).

[0062] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these embodiments of the invention pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the embodiments of the invention 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. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

CLAIMS

1. A method, comprising:

identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and

transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

2. The method as recited in Claim 1, wherein the identifying the one or more subframes from the plurality of backhaul uplink subframes is based on signaling information received from the evolved node B.

3. The method as recited in Claim 2, wherein the signaling information comprises information for specifying a periodicity or location of the one or more subframes among backhaul uplink subframes.

4. A method, comprising:

transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe,

wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

5. The method as recited in Claim 4, wherein the transmitting the sounding reference signal in the last symbol in the first slot of the backhaul uplink subframe is scheduled by the evolved node B using signaling information.

6. A method, comprising:

scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink

transmission from the relay node to an evolved node B.

7. The method as recited in Claim 6, wherein the scheduling the transmitting by the relay node the sounding reference signal in the backhaul uplink subframe is based upon a timer in the evolved node B, and the method further comprises:

upon expiration of a predetermined time period, forcing the relay node to transmit the sounding reference in a second slot of the backhaul uplink subframe; and

initiating the timer.

8. An apparatus, comprising:

means for identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and

means for transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

9. The apparatus as recited in Claim 8, wherein the means for identifying the one or more subframes from the plurality of backhaul uplink subframes is based on signaling information received from the evolved node B.

10. The apparatus as recited in Claim 9, wherein the signaling information comprises information for specifying a periodicity or location of the one or more subframes among backhaul uplink subframes.

11. An apparatus, comprising:

means for transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe,

wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

12. The apparatus as recited in Claim 11, wherein the means for transmitting the sounding reference signal in the last symbol of the first slot of the backhaul uplink subframe is scheduled by the evolved node B using signaling information.

13. An apparatus, comprising:

means for scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to an evolved node B.

14. The apparatus as recited in Claim 13, wherein the means for scheduling the transmitting by the relay node the sounding reference signal in the backhaul uplink subframe is based upon a timer in the evolved node B, and the apparatus further comprises:

means for forcing the relay node to transmit the sounding reference in a second slot of the backhaul uplink subframe upon expiration of a predetermined time period; and

means for initiating the timer.

15. An apparatus, comprising:

at least one processor, and

at least one memory including computer program code,

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

identify one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and

transmit physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

16. The apparatus as recited in Claim 15, wherein the apparatus is caused to identify the one or more subframes from the plurality of backhaul uplink subframes based on signaling information received from the evolved node B.

17. The apparatus as recited in Claim 16, wherein the signaling information comprises information for specifying a periodicity or location of the one or more subframes among backhaul uplink subframes.

18. An apparatus, comprising:

at least one processor, and

at least one memory including compute program code,

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

transmit a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe,

wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

19. The apparatus as recited in Claim 18, wherein the apparatus is caused to transmit the sounding reference signal in the last symbol of the first slot in the backhaul uplink subframe based on scheduling by the evolved node B using signaling information.

20. An apparatus, comprising:

at least one processor, and

at least one memory including compute program code,

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

schedule transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to an evolved node B.

21. The apparatus as recited in Claim 20, wherein the apparatus is caused to schedule the transmitting by the relay node the sounding reference signal in the backhaul uplink subframe based upon a timer in the evolved node B, and the at least one memory and the computer program code are further configured to cause the apparatus to perform:

force the relay node to transmit the sounding reference in a second slot of the backhaul uplink subframe upon expiration of a predetermined time period; and

initiate the timer.

22. A computer program product, comprising at least one computer readable storage medium having a computer readable program code portion stored thereon, the computer readable program code portion comprising:

program code instructions for identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node; and

program code instructions for transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes.

23. A computer program product, comprising at least one computer readable storage medium having a computer readable program code portion stored thereon, the computer readable program code portion comprising:

program code instructions for transmitting a sounding reference signal in a last symbol in a first slot of a backhaul uplink subframe,

wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.

24. A computer program product, comprising at least one computer readable storage medium having a computer readable program code portion stored thereon, the computer readable program code portion comprising:

program code instructions for scheduling transmitting, by a relay node, a sounding reference signal in a backhaul uplink subframe, wherein each backhaul uplink subframe has been split into two slots in a time domain including one slot being used for access uplink transmission from a user equipment to the relay node and another slot being used for backhaul uplink transmission from the relay node to an evolved node B.

25. The apparatus as recited in Claim 8, wherein the apparatus comprises the relay node.

26. The apparatus as recited in Claim 11, wherein the apparatus comprises the relay node.

27. The apparatus as recited in Claim 13, wherein the apparatus comprises the evolved node B.

28. The apparatus as recited in Claim 15, wherein the apparatus comprises the relay node.

29. The apparatus as recited in Claim 18, wherein the apparatus comprises the relay node.

30. The apparatus as recited in Claim 20, wherein the apparatus comprises the evolved node B.

1

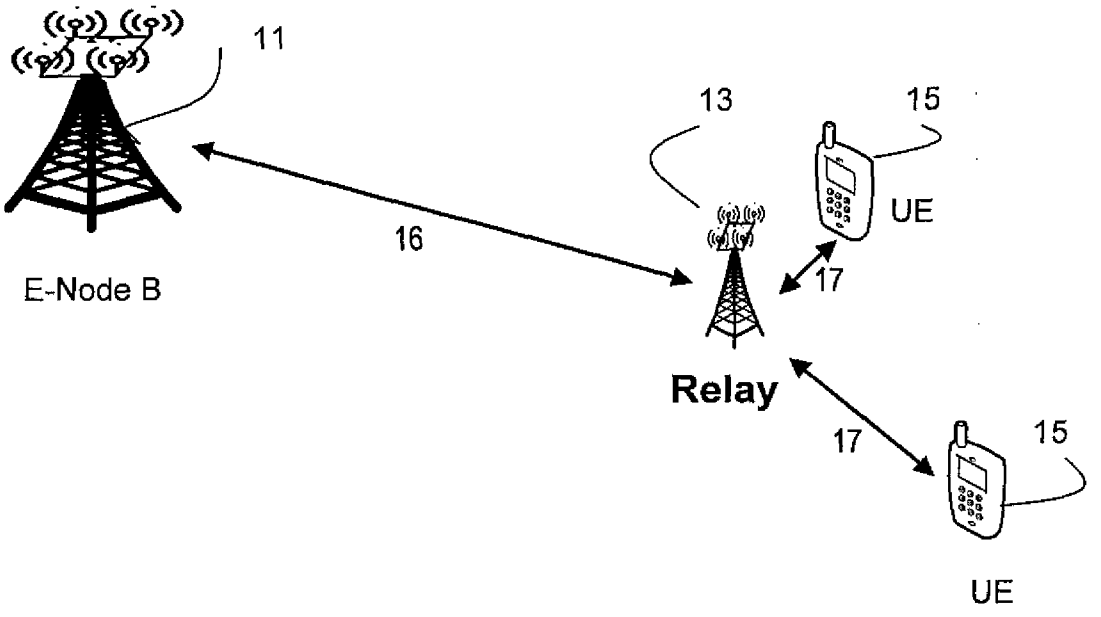

Fig. 1

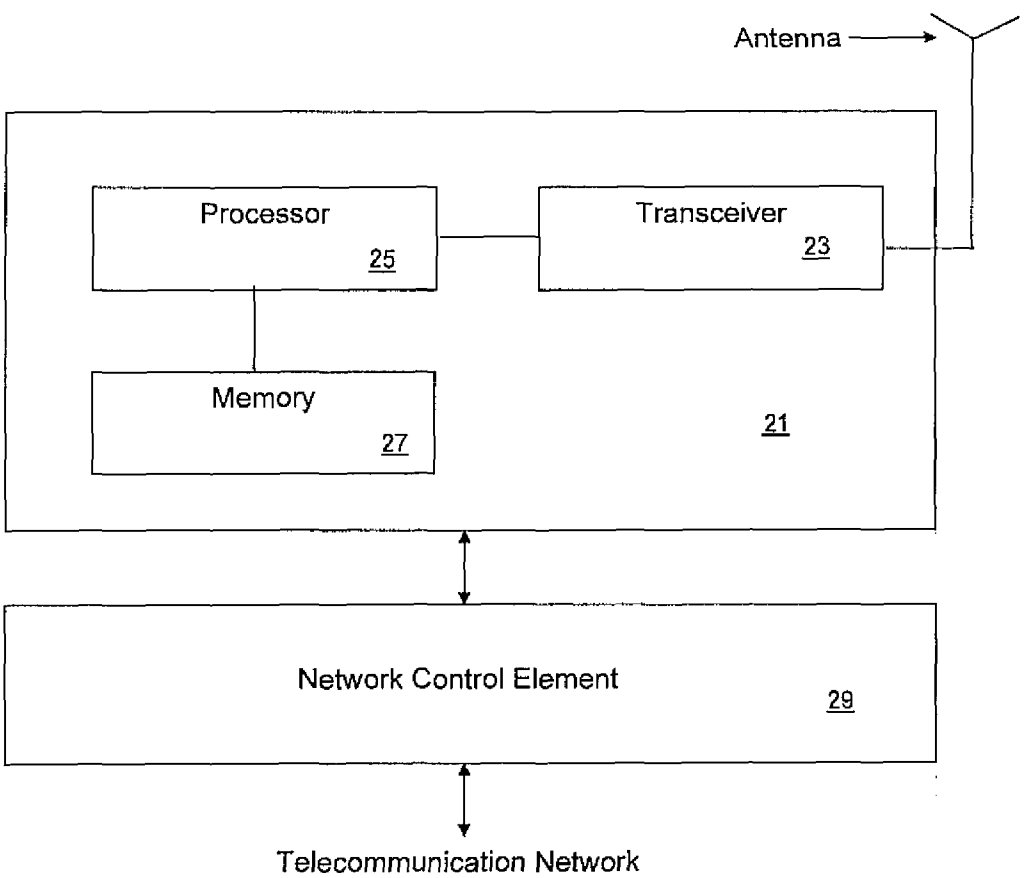
Antenna
Processor
25
Transceiver
23
Memory
27
21
Network Control Element
29
Telecommunication Network

Fig. 2

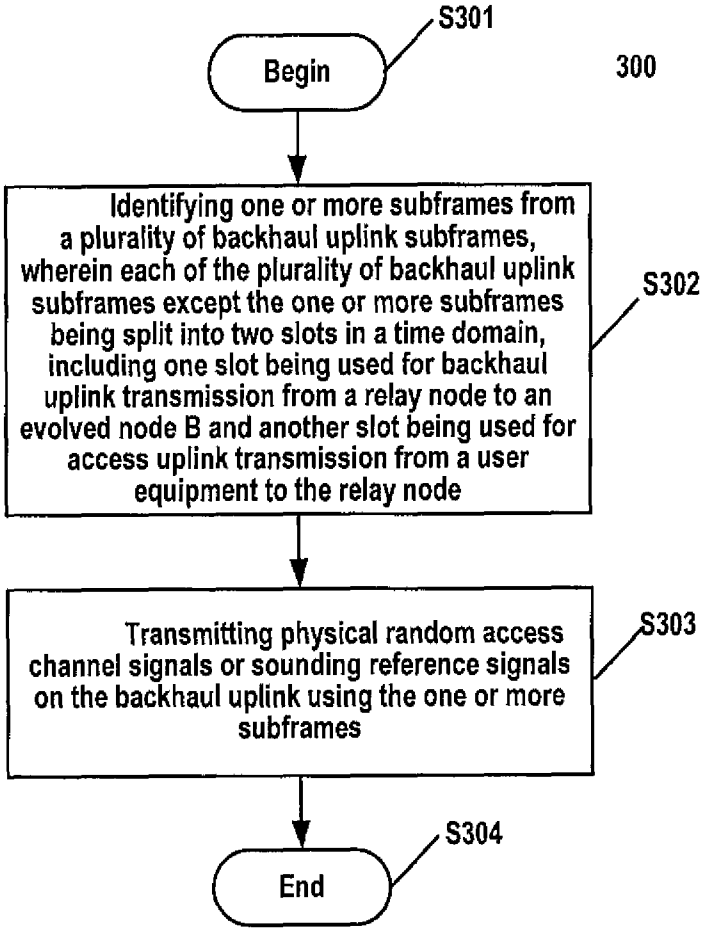
S301
Begin
300
Identifying one or more subframes from a plurality of backhaul uplink subframes, wherein each of the plurality of backhaul uplink subframes except the one or more subframes being split into two slots in a time domain, including one slot being used for backhaul uplink transmission from a relay node to an evolved node B and another slot being used for access uplink transmission from a user equipment to the relay node
S302
Transmitting physical random access channel signals or sounding reference signals on the backhaul uplink using the one or more subframes
S303
End
S304

Fig. 3

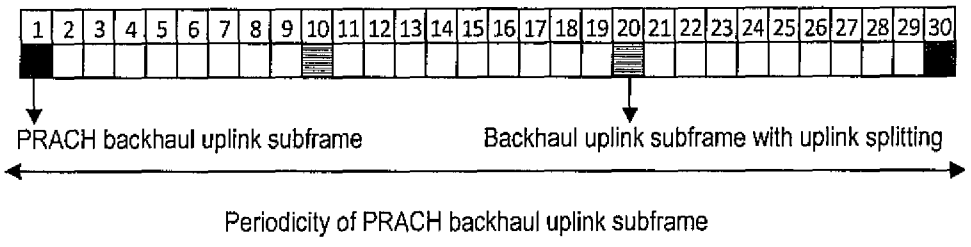
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
PRACH backhaul uplink subframe
Backhaul uplink subframe with uplink splitting
Periodicity of PRACH backhaul uplink subframe

Fig. 4

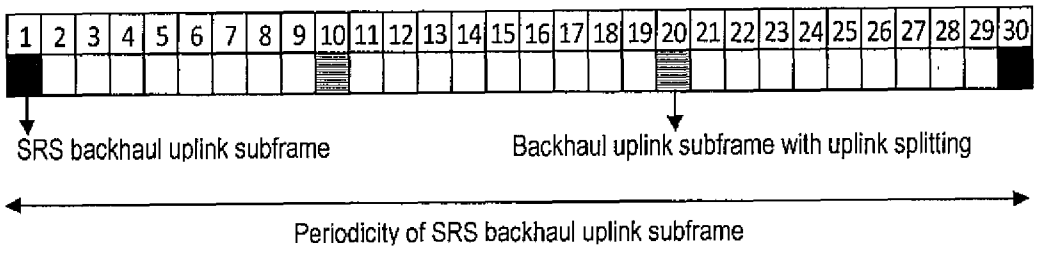
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
SRS backhaul uplink subframe
Backhaul uplink subframe with uplink splitting
Periodicity of SRS backhaul uplink subframe

Fig. 5

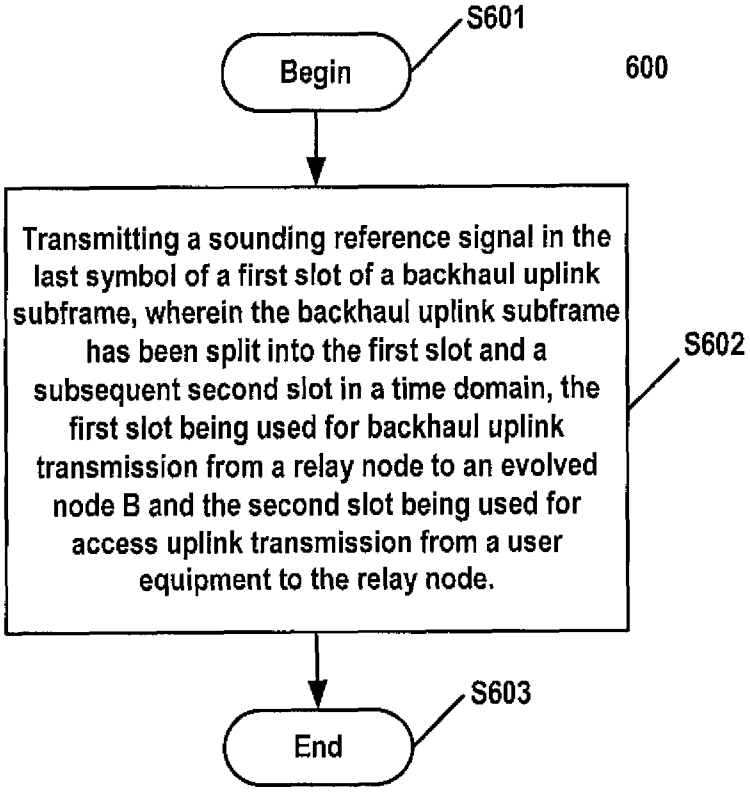
S601
Begin
600
Transmitting a sounding reference signal in the last symbol of a first slot of a backhaul uplink subframe, wherein the backhaul uplink subframe has been split into the first slot and a subsequent second slot in a time domain, the first slot being used for backhaul uplink transmission from a relay node to an evolved node B and the second slot being used for access uplink transmission from a user equipment to the relay node.
S602
S603
End

Fig. 6

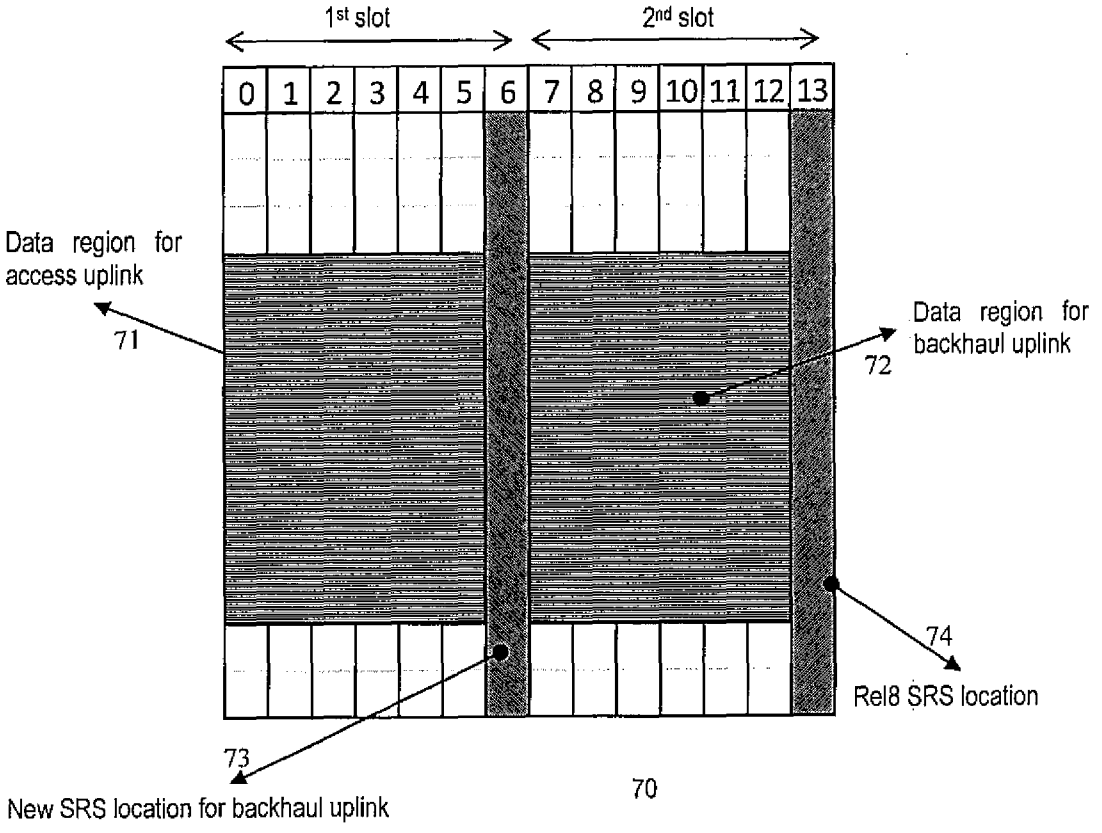
1st slot
2nd slot
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Data region for access uplink
71
Data region for backhaul uplink
72
74
Rel8 SRS location
73
New SRS location for backhaul uplink
70

Fig. 7

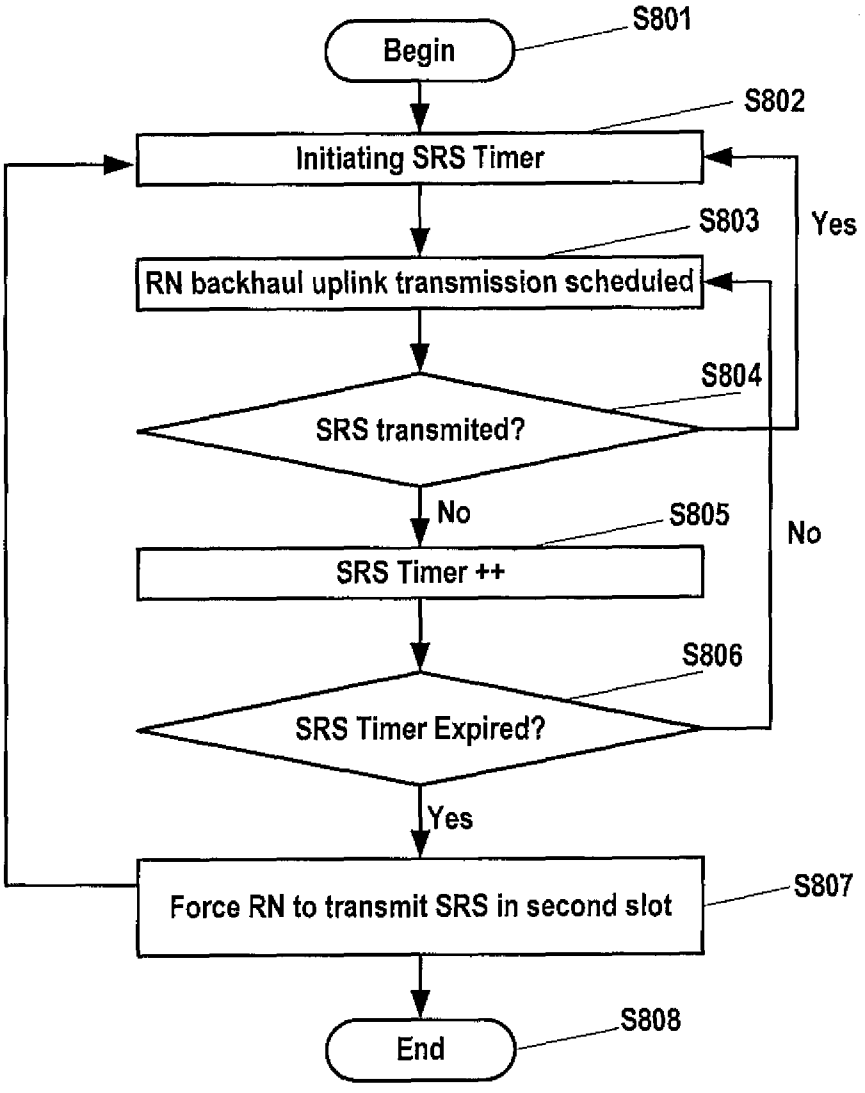
Begin
S801
Initiating SRS Timer
S802
RN backhaul uplink transmission scheduled
S803
SRS transmited?
S804
Yes
No
SRS Timer ++
S805
No
SRS Timer Expired?
S806
Yes
Force RN to transmit SRS in second slot
S807
End
S808

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2010/071726

A. CLASSIFICATION OF SUBJECT MATTER

H04L 12/56 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H04L; H04Q; H04W; H04B; H04J

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) WPI, EPODOC, CNPAT, IEEE, 3GPP: sub-frame, slot, split, backhaul link, access link, sounding reference signal, SRS, relay+, eNB, evolved Node B

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	NOKIA et al., "Improved Access-backhaul Partition Scheme for TDD Relay", 3GPP TSG-RAN WG1 Meeting #60 R1- 101439, 22 - 26 Feb. 2010 (22-26.02.2010), section 3	1-30
Y	CN101335713A (ZTE CORPORATION) 31 Dec. 2008 (31.12.2008) Page 1 Paragraph 2 to Page 2 Paragraph 6 of description	1-3, 8-10, 15-17, 22, 25, 28
Y	CN101394251A (ZTE CORPORATION) 25 Mar. 2009 (25.03.2009) Page 4 paragraph 1 of description	1-3, 8-10, 15-27, 22, 25, 28
Y	CN101106395A (ZTE CORPORATION) 16 Jan. 2008 (16.01.2008) Page 6 Paragraph 1 and Page 6 last Paragraph to Page 7 Paragraph 1 of description, Fig. 6	4-7, 11-14, 18-21, 23-24, 26-27, 29-30
A	Ericsson, "Text proposal on type 1 relaying", TSG-RAN WG1 Meeting #56 R1-091112, 9-13 February 2009 (09-13.02.2009), the whole document	1-30

☐ 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
15 Dec. 2010 (15.12.2010)	**20 Jan. 2011 (20.01.2011)**
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 YAN, Yan Telephone No. (86-10)62413301

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2010/071726

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101335713A	31.12.2008	None	
CN101394251A	25.03.2009	WO2010/009650A1	28.01.2010
CN101106395A	16.01.2008	None	