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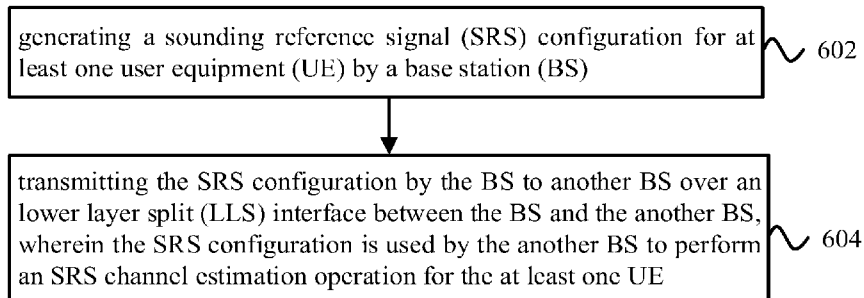


Figure 6

(57) Abstract: The present invention discloses methods and apparatuses for an uplink performance improvement in a lower layer split (LLS) RAN architecture. The method performed by a first base station (BS) comprises the following steps: receiving a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a second BS over the LLS interface between the first BS and the second BS, wherein the SRS configuration is used by the first BS to perform an SRS channel estimation (CE) operation for the at least one UE; receiving an SRS sequence from the at least one UE; and performing the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.



**METHODS AND APPARATUSES FOR AN UPLINK PERFORMANCE
IMPROVEMENT IN A LOWER LAYER SPLIT (LLS) RADIO ACCESS
NETWORK (RAN) ARCHITECTURE**

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to methods and apparatuses for an uplink performance improvement in a lower layer split (LLS) radio access network (RAN) architecture.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as a base station (BS), which may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g. time-domain resources (e.g. symbols, slots, subframes, frames, or the like) or frequency-domain resources (e.g. subcarriers, carriers, or the like). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g. sixth generation (6G)).

SUMMARY

[0003] An article "a" before an element is unrestricted and understood to refer to "at least one" of those elements or "one or more" of those elements. The terms "a," "at least one," "one or more," and "at least one of one or more" may be interchangeable. As used herein, including in the claims, "or" as used in a list of items (e.g. a list of items prefaced by a phrase such as "at least one of" or "one or more of" or "one or both of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e. A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is

described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on. Further, as used herein, including in the claims, a "set" may include one or more elements.

[0004] Some implementations of the present disclosure provide a first base station (BS). The first BS includes at least one memory; and at least one processor coupled to the at least one memory and configured to cause the first BS to: generate a sounding reference signal (SRS) configuration for at least one user equipment (UE); and transmit the SRS configuration to a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the second BS to perform an SRS channel estimation (CE) operation for the at least one UE.

[0005] In some implementations of the first BS described herein, the SRS configuration defines at least one SRS resource, and the at least one SRS resource is used by the at least one UE to generate at least one SRS sequence.

[0006] In some implementations of the first BS described herein, a first SRS resource within the at least one SRS resource is used by two or more UEs within the at least one UE to generate two or more SRS sequences.

[0007] In some implementations of the first BS described herein, the at least one SRS resource includes time domain related information, and the time domain related information includes at least one of the following: a starting symbol in a time slot; a total number of symbols for an SRS sequence transmission of the at least one UE; a total number of repetitions for an SRS transmission occasion of the at least one UE; a periodicity of the at least one SRS resource, and an offset corresponding to the periodicity for a periodic and semi-persistent SRS, wherein the periodicity and the offset are given in a total number of slots; or an offset between downlink control information (DCI) triggering an SRS transmission by the at least one UE and a slot for a reception of an SRS sequence, if the at least one SRS resource is associated with an aperiodic SRS.

[0008] In some implementations of the first BS described herein, the at least one SRS resource includes frequency domain related information, and the frequency domain related

information includes at least one of the following: an identifier (ID) of a resource block; a resource element mask within the resource block; or information used to determine a length of an SRS sequence for a partial frequency sounding, and the SRS sequence is generated by the UE based on the at least one SRS resource.

[0009] In some implementations of the first BS described herein, the at least one SRS resource includes at least one of the following: hopping finer granularity enabling finer granular hopping, and a set of cyclic shifts, if the SRS configuration is associated with cyclic shift hopping; a time-domain behaviour for a total number of repetitions for an SRS transmission occasion of the at least one UE, and a set of comb offsets, if the at least one SRS resource is associated with comb offset hopping; or a total number of one or more cyclic shifts for an antenna port, where a cyclic shift within the one or more cyclic shifts is associated with an identifier (ID) of the at least one UE.

[0010] In some implementations of the first BS described herein, the at least one SRS resource includes spatial domain related information, and the spatial domain related information includes at least one of the following: a configuration of spatial relation between a reference reference-signal (RS) and an SRS; or a configuration of a transmission configuration indicator (TCI) state of the at least one SRS resource.

[0011] In some implementations of the first BS described herein, the TCI state associates one or two downlink (DL) reference signals with a quasi-colocation type.

[0012] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to receive first information from the second BS, and the first information indicates at least one of the following: the second BS is capable to perform the SRS CE operation; or the second BS is not capable to perform the SRS CE operation.

[0013] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to receive SRS channel information for the at least one UE from the second BS over the LLS interface.

[0014] In some implementations of the first BS described herein, the SRS channel information includes at least one of the following: a signal to interference plus noise ratio

(SINR); a timing advance (TA) value between the second BS and the at least one UE; or one or more channel coefficients per physical resource block (PRB).

[0015] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to perform at least one of the following: considering that one or more PRBs are not used for the SRS CE operation, if the one or more channel coefficients for the one or more PRBs are set as a default value; or determining, from the SRS channel information, ID information of a starting PRB within each set of one or more sets of contiguous PRBs and a total PRB number of the each set of the one or more sets of contiguous PRBs, and consider that the one or more sets of contiguous PRBs are not used for the SRS CE operation.

[0016] In some implementations of the first BS described herein, at least one of the SRS configuration or the SRS channel information is carried in a section type message over the LLS interface.

[0017] In some implementations of the first BS described herein, if the SRS channel information is carried in the section type message, the section type message includes at least one of the following: a first indicator for indicating a type of the SRS channel information; a second indicator for indicating that the one or more channel coefficients per PRB are included in the section type message; a first section extension including the one or more channel coefficients per PRB; a second section extension indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation; or a third indicator for indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation.

[0018] In some implementations of the first BS described herein, the first BS is a distributed unit (DU) hosting high physical layers, and the second BS is a radio unit (RU) hosting low physical layers.

[0019] Some implementations of the present disclosure provide a processor for wireless communication, comprising at least one controller coupled with at least one memory and configured to cause the processor to: generate a sounding reference signal (SRS) configuration for at least one user equipment (UE); and transmit the SRS configuration to a base station (BS) over an lower layer split (LLS) interface between the processor and the BS,

wherein the SRS configuration is used by the BS to perform an SRS channel estimation (CE) operation for the at least one UE.

[0020] Some implementations of the present disclosure provide a method performed by a first base station (BS). The method includes: generating a sounding reference signal (SRS) configuration for at least one user equipment (UE); and transmitting the SRS configuration to a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the second BS to perform an SRS channel estimation (CE) operation for the at least one UE.

[0021] Some implementations of the present disclosure provide a first base station (BS). The first BS includes at least one memory; and at least one processor coupled to the at least one memory and configured to cause the first BS to: receive a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the first BS to perform an SRS channel estimation (CE) operation for the at least one UE; receive an SRS sequence from the at least one UE; and perform the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.

[0022] In some implementations of the first BS described herein, the SRS configuration defines at least one SRS resource, and the at least one SRS resource is used by the at least one UE to generate at least one SRS sequence.

[0023] In some implementations of the first BS described herein, a first SRS resource within the at least one SRS resource is used by two or more UEs within the at least one UE to generate two or more SRS sequences.

[0024] In some implementations of the first BS described herein, the at least one SRS resource includes time domain related information, and the time domain related information includes at least one of the following: a starting symbol in a slot; a total number of symbols for an SRS sequence transmission of the at least one UE; a total number of repetitions for an SRS transmission occasion of the at least one UE; a periodicity of the at least one SRS resource, and an offset corresponding to the periodicity for a periodic and semi-persistent SRS, wherein the periodicity and the offset are given in a total number of slots; or an offset

between downlink control information (DCI) triggering an SRS transmission by the at least one UE and a slot for a reception of an SRS sequence, if the at least one SRS resource is associated with an aperiodic SRS.

[0025] In some implementations of the first BS described herein, the at least one SRS resource includes frequency domain related information, and the frequency domain related information includes at least one of the following: an identifier (ID) of a resource block; a resource element mask within the resource block; or information used to determine a length of an SRS sequence for a partial frequency sounding, and the SRS sequence is generated by the UE based on the at least one SRS resource.

[0026] In some implementations of the first BS described herein, the at least one SRS resource includes at least one of the following: hopping finer granularity enabling finer granular hopping, and a set of cyclic shifts, if the SRS configuration is associated with cyclic shift hopping; a time-domain behaviour for a total number of repetitions for an SRS transmission occasion of the at least one UE, and a set of comb offsets, if the at least one SRS resource is associated with comb offset hopping; or a total number of one or more cyclic shifts for an antenna port, where a cyclic shift within the one or more cyclic shifts is associated with an identifier (ID) of the at least one UE.

[0027] In some implementations of the first BS described herein, the at least one SRS resource includes spatial domain related information, and the spatial domain related information includes at least one of the following: a configuration of spatial relation between a reference reference-signal (RS) and an SRS; or a configuration of a transmission configuration indicator (TCI) state of the at least one SRS resource.

[0028] In some implementations of the first BS described herein, the TCI state associates one or two downlink (DL) reference signals with a quasi-colocation type.

[0029] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to transmit first information to the second BS, and the first information indicates at least one of the following: the first BS is capable to perform the SRS CE operation; or the first BS is not capable to perform the SRS CE operation.

[0030] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to transmit the SRS channel information to the second BS over the LLS interface.

[0031] In some implementations of the first BS described herein, the SRS channel information includes at least one of the following: a signal to interference plus noise ratio (SINR); a timing advance (TA) value between the second BS and the at least one UE; or one or more channel coefficients per physical resource block (PRB).

[0032] In some implementations of the first BS described herein, the at least one processor is configured to cause the first BS to perform at least one of the following: if one or more PRBs are not used for the SRS CE operation, setting the one or more channel coefficients for the one or more PRBs as a default value; or if one or more sets of contiguous PRBs are not used for the SRS CE operation, adding ID information of a starting PRB within each set of the one or more sets of contiguous PRBs and a total PRB number of the each set of the one or more sets of contiguous PRBs into the SRS channel information.

[0033] In some implementations of the first BS described herein, at least one of the SRS configuration or the SRS channel information is carried in a section type message over the LLS interface.

[0034] In some implementations of the first BS described herein, if the SRS channel information is carried in the section type message, the section type message includes at least one of the following: a first indicator for indicating a type of the SRS channel information; a second indicator for indicating that the one or more channel coefficients per PRB are included in the section type message; a first section extension including the one or more channel coefficients per PRB; a second section extension indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation; or a third indicator for indicating the one or more sets of contiguous PRBs that are not used for the SRS CE operation.

[0035] In some implementations of the first BS described herein, the first BS is a radio unit (RU) hosting low physical layers, and the second BS is a distributed unit (DU) hosting high physical layers.

[0036] Some implementations of the present disclosure provide a processor for wireless communication, comprising at least one controller coupled with at least one memory and configured to cause the processor to: receive a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a base station (BS) over an lower layer split (LLS) interface between the processor and the BS, wherein the SRS configuration is used by the processor to perform an SRS channel estimation (CE) operation for the at least one UE; receive an SRS sequence from the at least one UE; and perform the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.

[0037] Some implementations of the present disclosure provide a method performed by a first base station (BS). The method includes: receiving a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the first BS to perform an SRS channel estimation (CE) operation for the at least one UE; receiving an SRS sequence from the at least one UE; and performing the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] Figure 1 illustrates an example of a wireless communications system in accordance with some aspects of the present disclosure.

[0039] Figure 2 illustrates an example of a processor 200 in accordance with some aspects of the present disclosure.

[0040] Figure 3 illustrates an example of a network equipment (NE) 300 in accordance with some aspects of the present disclosure.

[0041] Figure 4 illustrates a diagram of a logical architecture of an LLS RAN in accordance with some aspects of the present disclosure.

[0042] Figure 5 illustrates a diagram of a weight-based dynamic beamforming (WDBF) in accordance with some aspects of the present disclosure.

[0043] Figure 6 illustrates a flowchart of a method for transmitting an SRS configuration in accordance with some aspects of the present disclosure.

[0044] Figure 7 illustrates a flowchart of a method for receiving an SRS configuration in accordance with some aspects of the present disclosure.

[0045] Figure 8 illustrates a schematic diagram of an uplink performance improvement in an LLS RAN architecture in accordance with some aspects of the present disclosure.

DETAILED DESCRIPTION

[0046] In general, split RAN, in which a RAN architecture is split into centralized baseband units and distributed radio units, has gained traction and has proven to be effective in commercial RAN deployments over the past years. Such centralized architecture has both performance benefits (due to improved inter-cell/frequency coordination at the centralized baseband) and cost benefits (e.g. due to increased hardware/software pooling, reduced site rental and management costs). Therefore, with the challenging and diverse requirements for the radio systems, the need for such split RAN architecture is becoming ever more important. A typical lower layer split RAN architecture is shown in Figure 4, as defined by open radio access network (O-RAN).

[0047] **Figure 4** illustrates a diagram of a logical architecture of an LLS RAN in accordance with some aspects of the present disclosure.

- **O-RAN distributed unit (O-DU):** a logical node hosting PDCP (packet data convergence protocol), RRC (radio resource control), SDAP (service data adaptation protocol), RLC (radio link control), MAC (medium access protocol), High-PHY (physical) layers based on a lower layer functional split. The O-DU controls the operation of O-RUs. For example, the High-PHY layer includes the functionalities of scrambling, modulation, layer mapping, resource element mapping, IQ (in-phase quadrature) compression, etc.
- **O-RAN radio unit (O-RU):** a logical node hosting Low-PHY layer and RF (radio frequency) processing based on a lower layer functional split. The real-time aspects of control & user plane communication with the O-RU are controlled by the O-DU. For example, the Low-PHY layer includes the functionalities of IQ decompression, digital

beamforming, IFFT (inverse fast fourier transform) and CP (cyclic prefix) addition, digital to analog, analog beamforming, etc.

- **LLS (lower layer split)**: a logic interface between O-DU and O-RU when using a lower layer functional split. LLS control plane (LLS-C) is the lower layer split control plane, while LLS user plane (LLS-U) is the lower layer split user plane.

[0048] Currently, an approach is to limit the complexity of the O-RU at the same time reducing the LLS bitrate compared with time-domain fronthaul interface like CPRI (Common Public Radio Interface), for example, as shown in the Figure 5.

[0049] **Figure 5** illustrates a diagram of a weight-based dynamic beamforming (WDBF) in accordance with some aspects of the present disclosure. As can be seen from a baseline uplink (UL) solution as shown in the Figure 5, existing WDBF functions in O-RU includes Beamform which is a linear matrix operation on the signal from K antenna elements to M non-equalized layer streams and N spatial streams, FFT (fast fourier transform), raw SRS Extraction, and Channel information BFW calculation. Existing WDBF functions in O-DU includes DMRS (demodulation reference signal) weight calculation (DU), DMRS channel estimation (DU), DMRS extraction (DU), Combine (DU) which is a combining operation by mapping the signal from M non-equalized layer streams and N spatial streams to L non-equalized layer streams, Equalize (DU) which is a equalization operation by mapping signal from L non-equalized layers to L equalized layer streams, Layer Demapping, Demodulation, Decoding, SRS BFW calculation, and SRS channel estimation. In some cases, O-DU may also be named as DU. O-RU may also be named as RU.

[0050] However, in the current approach, the LLS bitrate reduction in UL may be much less than that in downlink (DL), e.g., requiring more LLS streams. The approach is still with bursty LLS bitrates due to the SRS CE (channel estimation). Therefore, the following issues need to be solved, but details regarding such issues have not been discussed yet:

- issue 1: how to enable an SRS CE function in the RU via LLS-C signalling, e.g., where to receive the SRS sequence from the UE?
- issue 2: how to enable an SRS CE function in the RU via LLS-C signalling to support multiple UEs allocated at the same time and frequency resource?

- issue 3: how to support non-contiguous PRB channel report by the RU?

[0051] Embodiments of the present disclosure aim to resolve the abovementioned issues 1, 2 and 3, to improve UL air interface performance by shifting certain processing functions from DU to RU while minimizing the LLS bitrate, e.g., the number of streams reduced to the number of layers. The embodiments of the present disclosure improve uplink performance by shifting an SRS CE function from the DU to the RU. Locating SRS CE in the RU may enable further optimization, e.g., the estimated SRS channel can be used for the dimension reduction function in DMRS-based beamforming, offload the CE from the DU to the RU in case of channel-information-based beamforming.

[0052] For example, some embodiments of the present disclosure define a new LLS-C procedure to convey an SRS configuration used for CE from the DU to the RU, and to convey SRS channel information from the RU to the DU. Some embodiments of the present disclosure introduce a new LLS-C message sent by the DU to setup an SRS configuration in the RU (e.g. an SRS configuration request message). For instance, the SRS configuration for an SRS resource may include the following:

- (1) Time domain related parameters used by the UE, including start position in a slot, number of symbols for the SRS reception.
 - a) For periodic and semi-persistent SRS, the periodicity and offset should be provided.
 - b) For aperiodic SRS, the available slot offset, which is the offset between the DCI triggering the SRS and the slot for the SRS reception, may be configured for the RU to determine the slot for the SRS reception.
- (2) Resource block (RB) and reMask are included to indicate the frequency domain information, where RB indicates the resource block ID and reMask indicates the resource element (RE) mask within the corresponding RB.
 - a) When partial frequency sounding is configured, the frequency scaling factor and the starting RB index should be provided as well.
- (3) Cyclic shift hopping and/or comb offset hopping related parameter(s).

(4) Spatial domain parameters include spatial relation info, SRS-TCI state or whether to follow the indicated unified TCI state for the RU to determine spatial receiving (Rx) filters for the SRS reception.

[0053] Some embodiments of the present disclosure introduce a new LLS-C message sent by the RU to provide the SRS channel information (e.g. an SRS report message). For instance, the channel information includes the SINR and/or TA value based on the SRS CE, and it is associated with the corresponding symbols and PRBs, per slot, per subframe and/or per frame. Some embodiments of the present disclosure introduce an indicator to indicate the type of channel information, i.e., SINR and/or a TA value. In some embodiments, channel coefficients (in-phase quadrature (IQ) sample) per PRB is provided together via a section extension.

[0054] Some embodiments of the present disclosure introduce a section type in an SRS configuration message to convey a UE specific SRS configuration. For instance, the UE specific SRS configuration includes the cyclic shift and the corresponding UE ID. Other SRS configurations may be common for multiple UEs. The SRS report may include SRS channel information, where each element in the SRS channel information is associated with the corresponding UE ID.

[0055] In some embodiments of the present disclosure, the CE without PRB report is set to a default value, e.g. 0. The DU may determine "the channel coefficients if PRB with value 0" as the PRB without channel reporting. In some other embodiments of the present disclosure, the PRB without channel reporting is provided by means of the off starting PRB and the total number of PRBs. On receipt of such information, the DU may determine the PRB which is without channel reporting.

[0056] In the present disclosure, a RU refers to a logical node hosting Low-PHY layer based on an LLS. In some cases, a RU may also host other functionalities, e.g., RF processing. A RU may also be named as "a RU hosting low physical layers," "a network node hosting low physical layers," or "a base station (BS) hosting low physical layers" or the like. A DU refers to a logical node hosting High-PHY layers based on an LLS. In some cases, a DU may also host other functionalities, e.g., PDCP layer, RRC layer, SDAP layer, RLC layer or MAC layer. A DU may also be named as "a DU hosting high physical layers,"

"a network node hosting high physical layers," or "a base station (BS) hosting high physical layers" or the like.

[0057] In the present disclosure, an SRS reception in a RU may be the same as an SRS transmission in a UE. For example, the reception comb related parameters in a RU could be the same as the transmission comb related parameters used by the UE. In the present disclosure, an SRS CE could be interpreted as a channel estimation operation based on SRS. SRS channel information may also be named as "SRS channel estimation information," "channel information of a UE based on SRS CE," "channel estimation information of a UE based on SRS" or the like.

[0058] More details of the embodiments of the present disclosure will be illustrated in the following text in combination with the appended drawings.

[0059] **Figure 1** illustrates an example of a wireless communications system 100 in accordance with some aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a long term evolution (LTE) network or an LTE-advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a new radio (NR) network, such as a 5G network, a 5G-advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including institute of electrical and electronics engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0060] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element,

a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g. receive signaling, transmit signaling) over a Uu interface.

[0061] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g. voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0062] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an internet-of-things (IoT) device, an internet-of-everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0063] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0064] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links (e.g. S1, N2, or network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g. via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0065] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g. a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g. a serving gateway (S-GW), a packet data network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g. data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0066] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g. via an S1, N2, or another network interface). The packet data network may include an application server. In some implementations, one or more UEs 104 may communicate with the application server. A UE 104 may establish a session (e.g. a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g. control information, data, and the like) between the UE 104 and the application server using the established session (e.g. the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g. one or more network functions of the CN 106).

[0067] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g. time resources (e.g. symbols,

slots, subframes, frames, or the like) or frequency resources (e.g. subcarriers, carriers)) to perform various operations (e.g. wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e. multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0068] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g. $\mu=0$) may be associated with a first subcarrier spacing (e.g. 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g. $\mu=0$) associated with the first subcarrier spacing (e.g. 15 kHz) may utilize one slot per subframe. A second numerology (e.g. $\mu=1$) may be associated with a second subcarrier spacing (e.g. 30 kHz) and a normal cyclic prefix. A third numerology (e.g. $\mu=2$) may be associated with a third subcarrier spacing (e.g. 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g. $\mu=3$) may be associated with a fourth subcarrier spacing (e.g. 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g. $\mu=4$) may be associated with a fifth subcarrier spacing (e.g. 240 kHz) and a normal cyclic prefix.

[0069] A time interval of a resource (e.g. a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0070] Additionally or alternatively, a time interval of a resource (e.g. a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g. quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For

instance, the first, second, third, fourth, and fifth numerologies (i.e. $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g. quantity) of symbols (e.g. OFDM symbols). In some implementations, the number (e.g. quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g. applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g. $\mu=0$) associated with a first subcarrier spacing (e.g. 15 kHz) may be used interchangeably between subframes and slots.

[0071] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (310 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 200 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g. control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0072] FR1 may be associated with one or multiple numerologies (e.g. at least three numerologies). For example, FR1 may be associated with a first numerology (e.g. $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g. $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g. $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g. at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g. $\mu=2$),

which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g. $\mu=3$), which includes 120 kHz subcarrier spacing.

[0073] **Figure 2** illustrates an example of a processor 200 in accordance with some aspects of the present disclosure. The processor 200 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 200 may include a controller 202 configured to perform various operations in accordance with examples as described herein. The processor 200 may optionally include at least one memory 204, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 200 may optionally include one or more arithmetic-logic units (ALUs) 206. One or more of these components may be in electronic communication or otherwise coupled (e.g. operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g. buses).

[0074] The processor 200 may be a processor chipset and include a protocol stack (e.g. a software stack) executed by the processor chipset to perform various operations (e.g. receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g. memory local to or included in the processor chipset (e.g. the processor 200) or other memory (e.g. random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0075] The controller 202 may be configured to manage and coordinate various operations (e.g. signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 200 to cause the processor 200 to support various operations in accordance with examples as described herein. For example, the controller 202 may operate as a control unit of the processor 200, generating control signals that manage the operation of various components of the processor 200. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0076] The controller 202 may be configured to fetch (e.g. obtain, retrieve, receive) instructions from the memory 204 and determine subsequent instruction(s) to be executed to cause the processor 200 to support various operations in accordance with examples as described herein. The controller 202 may be configured to track memory address of instructions associated with the memory 204. The controller 202 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 202 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 200 to cause the processor 200 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 202 may be configured to manage flow of data within the processor 200. The controller 202 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 200.

[0077] The memory 204 may include one or more caches (e.g. memory local to or included in the processor 200 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 204 may reside within or on a processor chipset (e.g. local to the processor 200). In some other implementations, the memory 204 may reside external to the processor chipset (e.g. remote to the processor 200).

[0078] The memory 204 may store computer-readable, computer-executable code including instructions that, when executed by the processor 200, cause the processor 200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 202 and/or the processor 200 may be configured to execute computer-readable instructions stored in the memory 204 to cause the processor 200 to perform various functions. For example, the processor 200 and/or the controller 202 may be coupled with or to the memory 204, the processor 200, the controller 202, and the memory 204 may be configured to perform various functions described herein. In some examples, the processor 200 may include multiple processors and the memory 204 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple

memories, which may, individually or collectively, be configured to perform various functions herein.

[0079] The one or more ALUs 206 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 206 may reside within or on a processor chipset (e.g. the processor 200). In some other implementations, the one or more ALUs 206 may reside external to the processor chipset (e.g. the processor 200). One or more ALUs 206 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 206 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 206 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 206 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 206 to handle conditional operations, comparisons, and bitwise operations.

[0080] The processor 200 may support wireless communication in accordance with examples as disclosed herein.

[0081] In some implementations, the processor 200 may be configured to support means for performing operations of a BS (e.g. a DU hosting high physical layers) as described with respect to Figure 6. For example, the processor 200 may be configured to or operable to support: a means for generating an SRS configuration for at least one UE; and a means for transmitting the SRS configuration to another BS over an LLS interface between the BS and the another BS, wherein the SRS configuration is used by the another BS to perform an SRS channel estimation (CE) operation for the at least one UE.

[0082] In some implementations, the processor 200 may be configured to support means for performing operations of a BS (e.g. a RU hosting low physical layers) as described with respect to Figure 7. For example, the processor 200 may be configured to or operable to support: a means for receiving an SRS configuration for at least one UE from another BS over an LLS interface between the BS and the another BS, wherein the SRS configuration is used by the BS to perform an SRS CE operation for the at least one UE; a means for

receiving an SRS sequence from the at least one UE; and a means for performing the SRS CE operation to determine SRS channel information for the at least one UE based on the received SRS sequence.

[0083] It should be appreciated by persons skilled in the art that the components in exemplary processor 200 may be changed, for example, some of the components in exemplary processor 200 may be omitted or modified or new component(s) may be added to exemplary processor 200, without departing from the spirit and scope of the disclosure. For example, in some embodiments, the processor 200 may not include the ALUs 206.

[0084] **Figure 3** illustrates an example of a NE 300 in accordance with some aspects of the present disclosure. The NE 300 may include a processor 302, a memory 304, a controller 306, and a transceiver 308. The processor 302, the memory 304, the controller 306, or the transceiver 308, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g. operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0085] The processor 302, the memory 304, the controller 306, or the transceiver 308, or various combinations or components thereof may be implemented in hardware (e.g. circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0086] The processor 302 may include an intelligent hardware device (e.g. a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 302 may be configured to operate the memory 304. In some other implementations, the memory 304 may be integrated into the processor 302. The processor 302 may be configured to execute computer-readable instructions stored in the memory 304 to cause the NE 300 to perform various functions of the present disclosure.

[0087] The memory 304 may include volatile or non-volatile memory. The memory 304 may store computer-readable, computer-executable code including instructions when executed by the processor 302 cause the NE 300 to perform various functions described

herein. The code may be stored in a non-transitory computer-readable medium such the memory 304 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0088] In some implementations, the processor 302 and the memory 304 coupled with the processor 302 may be configured to cause the NE 300 to perform one or more of the functions described herein (e.g. executing, by the processor 302, instructions stored in the memory 304). For example, the processor 302 may support wireless communication at the NE 300 in accordance with examples as disclosed herein. For example, the NE 300 may be configured to support means for performing the operations as described with respect to Figures 6 and 7 as described below.

[0089] In some implementations, the NE 300 may be a BS (e.g. a DU hosting high physical layers) as described with respect to Figure 6. The NE 300 may be configured to support: a means for generating an SRS configuration for at least one UE; and a means for transmitting the SRS configuration to another BS over an LLS interface between the BS and the another BS, wherein the SRS configuration is used by the another BS to perform an SRS CE operation for the at least one UE.

[0090] In some implementations, the NE 300 may be a BS (e.g. a RU hosting low physical layers) as described with respect to Figure 7. The NE 300 may be configured to support: a means for receiving an SRS configuration for at least one UE from another BS over an LLS interface between the BS and the another BS, wherein the SRS configuration is used by the BS to perform an SRS CE operation for the at least one UE; a means for receiving an SRS sequence from the at least one UE; and a means for performing the SRS CE operation to determine SRS channel information for the at least one UE based on the received SRS sequence.

[0091] The controller 306 may manage input and output signals for the NE 300. The controller 306 may also manage peripherals not integrated into the NE 300. In some implementations, the controller 306 may utilize an operating system such as iOS®,

ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 306 may be implemented as part of the processor 302.

[0092] In some implementations, the NE 300 may include at least one transceiver 308. In some other implementations, the NE 300 may have more than one transceiver 308. The transceiver 308 may represent a wireless transceiver. The transceiver 308 may include one or more receiver chains 310, one or more transmitter chains 312, or a combination thereof. The means for receiving or the means for transmitting abovementioned in the processor 302 may be implemented via at least one transceiver 308.

[0093] A receiver chain 310 may be configured to receive signals (e.g. control information, data, packets) over a wireless medium. For example, the receiver chain 310 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 310 may include at least one amplifier (e.g. a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 310 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 310 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0094] A transmitter chain 312 may be configured to generate and transmit signals (e.g. control information, data, packets). The transmitter chain 312 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 312 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 312 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0095] It should be appreciated by persons skilled in the art that the components in exemplary NE 300 may be changed, for example, some of the components in exemplary NE 300 may be omitted or modified or new component(s) may be added to exemplary NE 300,

without departing from the spirit and scope of the disclosure. For example, in some embodiments, the NE 300 may not include the controller 306.

[0096] **Figure 6** illustrates a flowchart of a method for transmitting an SRS configuration in accordance with some aspects of the present disclosure. The operations of the method may be implemented by a BS, e.g. a DU hosting high physical layers, as described herein. In some implementations, the BS may execute a set of instructions to control the function elements of the BS to perform the described functions. In some implementations, aspects of operations 602 and 604 may be performed by NE 300 as described with reference to Figure 3. Each of operations 602 and 604 may be performed in accordance with examples as described herein. Specific examples are described in the embodiments of Figure 8 as follows.

[0097] At 602, the method includes generating, by a BS (denoted as BS #1), an SRS configuration (denoted as SRS configuration #1) for at least one UE (denoted as UE #1). At 604, the method includes transmitting SRS configuration #1 by BS #1 to another BS (denoted as BS #2) over an LLS interface between BS #1 and BS #2. BS #1 may be a DU hosting high physical layers. BS #2 may be a RU hosting low physical layers. SRS configuration #1 may be used by BS #2 to perform an SRS channel estimation (CE) operation (or function) for UE #1, e.g. at the same time and frequency resource.

[0098] In some implementations, SRS configuration #1 is carried in a section type message (for example, an SRS configuration request, e.g. Section Type X as described in the embodiments of in Figure 8) over the LLS interface.

[0099] SRS configuration #1 may define at least one SRS resource (denoted as SRS resource #1), which is used by UE #1 to generate at least one SRS sequence. For example, one SRS resource within SRS resource #1 may be used by two or more UEs within UE #1 to generate two or more SRS sequences, respectively. Another SRS resource within SRS resource #1 may be used by one UE within UE #1 to generate one SRS sequence.

[0100] In some implementations, SRS resource #1 includes time domain related information, which includes at least one of the following:

(1) a starting symbol in a time slot, e.g. *startSymbolId*;

- (2) a total number of symbols for an SRS sequence transmission of UE #1, i.e. a total number of symbols for an SRS sequence reception at BS #2, e.g. *numSymbol*;
- (3) a total number of repetitions for an SRS transmission occasion of UE #1, e.g. *repetitionFactor*;
- (4) a periodicity of the at least one SRS resource (e.g. *periodicity*), and an offset corresponding to the periodicity for a periodic and semi-persistent SRS (e.g. *offset*), wherein the periodicity and the offset are given in number of slots; or
- (5) an offset (or difference) between DCI triggering an SRS transmission by UE #1 and a slot for a reception of an SRS sequence, if SRS resource #1 is associated with an aperiodic SRS.

[0101] In some implementations, SRS resource #1 includes frequency domain related information, which includes at least one of the following:

- (1) an ID of a resource block (RB), e.g. *rb*;
- (2) a resource element mask within the resource block, e.g. *reMask*; or
- (3) information used to determine a length of an SRS sequence for a partial frequency sounding, and the SRS sequence is generated by the UE based on the at least one SRS resource, e.g. *startRbIndexAndFreqScalingFactor*.

[0102] In some implementations, SRS resource #1 includes at least one of the following:

- (1) hopping finer granularity enabling finer granular hopping (e.g. *hoppingFinerGranularity*), and a set of cyclic shifts (e.g. *hoppingSubset*), if SRS configuration #1 is associated with cyclic shift hopping;
- (2) a time-domain behaviour (e.g. *hoppingWithRepetition*) for a total number of repetitions for an SRS transmission occasion of UE #1 (e.g. *repetition factor*), and a set of comb offsets (e.g. *hoppingSubset*), if the at least one SRS resource is associated with comb offset hopping; or
- (3) a total number of one or more cyclic shifts for an antenna port, where a cyclic shift within the one or more cyclic shifts is associated with an ID of UE #1.

[0103] In some implementations, SRS resource #1 includes spatial domain related information, which includes at least one of the following:

- (1) a configuration of spatial relation between a reference RS and an SRS, e.g. *spatialRelationInfo*; or
- (2) a configuration of a TCI state of the at least one SRS resource, e.g. *tciParam*. The TCI state may associate one or two DL reference signals with a quasi-colocation type.

[0104] In some implementations of the method, BS #1 may receive, from BS #2, information (denoted as information #1) which indicates at least one of the following:

- (1) BS #2 is capable to perform the SRS CE operation, e.g. in an SRS configuration response; or
- (2) BS #2 is not capable to perform the SRS CE operation, e.g. in an SRS configuration failure.

[0105] In some implementations of the method, BS #1 may receive SRS channel information (denoted as channel information #1) for UE #1 from BS #2 over the LLS interface, e.g. via an SRS report. For example, channel information #1 includes at least one of the following:

- (1) a SINR;
- (2) a TA value between BS #2 and UE #1; or
- (3) one or more channel coefficients per PRB.

[0106] In some implementations of the method, BS #1 may consider that one or more PRBs are not used for the SRS CE operation, if the one or more channel coefficients for the one or more PRBs are set as a default value, e.g. 0. In some other implementations of the method, BS #1 may determine, from channel information #1, ID information of a starting PRB (e.g. *offStartPrb*) within each set of one or more sets of contiguous PRBs and a total PRB number (e.g. *numOffStartPrb*) of the each set of the one or more sets of contiguous PRBs, and consider that the one or more sets of contiguous PRBs are not used for the SRS CE operation.

[0107] In some implementations, channel information #1 is carried in a section type message (e.g. Section Type Y as described in the embodiments of in Figure 8) over the LLS interface. For example, the section type message includes at least one of the following:

- (1) an indicator for indicating a type of channel information #1, e.g. *reportType*;
- (2) an indicator for indicating that the one or more channel coefficients per PRB are included in the section type message, e.g. *mf*;
- (3) a section extension including the one or more channel coefficients per PRB, e.g. Section Extension M;
- (4) a section extension indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation, e.g. Section Extension P; or
- (5) an indicator for indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation, e.g. *mf*.

[0108] **Figure 7** illustrates a flowchart of a method for receiving an SRS configuration in accordance with some aspects of the present disclosure. The operations of the method may be implemented by a BS, e.g. a RU hosting low physical layers, as described herein. In some implementations, the BS may execute a set of instructions to control the function elements of the BS to perform the described functions. In some implementations, aspects of operations 702, 704 and 706 may be performed by NE 300 as described with reference to Figure 3. Each of operations 702, 704 and 706 may be performed in accordance with examples as described herein. Specific examples are described in the embodiments of Figure 8 as follows.

[0109] At 702, the method includes receiving an SRS configuration (e.g. SRS configuration #1 as described in the embodiments of Figure 6) for at least one UE (e.g. UE #1 as described in the embodiments of Figure 6) by a BS (e.g. BS #2 as described in the embodiments of Figure 6) from another BS (e.g. BS #1 as described in the embodiments of Figure 6) over an LLS interface between BS #1 and BS #2. BS #1 may be a RU hosting low physical layers. BS #2 may be a DU hosting high physical layers.

[0110] The SRS configuration can be used by BS #1 to perform an SRS CE operation for UE #1. The SRS configuration may include the same elements as those of SRS

configuration #1 as described in the embodiments of Figure 6. For instance, the SRS configuration defines at least one SRS resource (e.g. SRS resource #1 as described in the embodiments of Figure 6), which is used by UE #1 to generate at least one SRS sequence. The at least one SRS resource may include the same elements as those of SRS resource #1 as described in the embodiments of Figure 6.

[0111] At 704, the method includes receiving an SRS sequence by BS #2 from UE #1. At 706, the method includes performing the SRS CE operation by BS #2 based on the received SRS sequence, to determine SRS channel information (e.g. channel information #1 as described in the embodiments of Figure 6) for UE #1.

[0112] In some implementations of the method, BS #2 may transmit information (e.g. information #1 as described in the embodiments of Figure 6) to BS #1, which indicates at least one of the following:

- (1) BS #2 is capable to perform the SRS CE operation, e.g. in an SRS configuration response;
or
- (2) BS #2 is not capable to perform the SRS CE operation, e.g. in an SRS configuration failure.

[0113] In some implementations of the method, BS #2 may transmit the SRS channel information to BS #1 over the LLS interface. The SRS channel information may include the same elements as those of channel information #1 as described in the embodiments of Figure 6. For example, the SRS channel information includes a SINR, a TA value between BS #1 and UE #1, and/or one or more channel coefficients per PRB.

[0114] In some implementations of the method, BS #2 may perform at least one of the following:

- (1) if one or more PRBs are not used for the SRS CE operation, setting the one or more channel coefficients for the one or more PRBs as a default value, e.g. 0; or
- (2) if one or more sets of contiguous PRBs are not used for the SRS CE operation, adding ID information of a starting PRB within each set of the one or more sets of contiguous PRBs and a total PRB number of the each set of the one or more sets of contiguous PRBs into the SRS channel information.

[0115] It should be noted that the method described in Figure 6 or Figure 7 describes possible implementations, and that the operations and the steps may be rearranged or otherwise eliminated or modified and that other implementations are possible, without departing from the spirit and scope of the disclosure. Following text describe specific embodiments of Figure 6 or Figure 7 according to different cases.

[0116] **Figure 8** illustrates a schematic diagram of an uplink performance improvement in an LLS RAN architecture in accordance with some aspects of the present disclosure. Embodiments of Figure 8 provide solutions for a RU based SRS channel estimation (CE) for a UE. Some embodiments of Figure 8 aim to solve issue 1 and issue 2 (denoted as Embodiment #1). Some other embodiments of Figure 8 aim to solve issue 3 (denoted as Embodiment #2).

[0117] **Embodiment #1**

[0118] At 801, a DU may send an SRS configuration request to a RU, to provide an SRS configuration used for CE by the RU. The SRS configuration may include one or multiple SRS resources. For simplicity, the following description uses an SRS resource for example, e.g. the SRS configuration is equal to the SRS resource.

[0119] For example, the SRS configuration based on O-RAN LLS-C is shown in Format #1 as below, where a new section type (Section Type X) is introduced to provide the SRS configuration from the DU to the RU. In O-RAN LLS-C, a section defines the characteristics of LLS-U data to be transferred or received from a beam with one pattern ID.

[0120] The SRS configuration is provided per symbol, per slot, per subframe and per frame. That is, the symbol ID, slot ID, subframe ID and frame ID are provided. In one example, the symbol ID may be provided by the starting symbol ID (*startSymbolId*) and the symbol number increment flag (*symInc*), where the symbol number increment flag indicates the symbol number should be increased to the next symbol, and the new symbol number should be used.

[0121] The SRS configuration is provided with starting PRB (*startPrb*) and number of contiguous PRBs (*numPrb*), which indicates the PRB in the RB grid defined by corresponding frequency offset and frame structure. The starting PRB indicates the first PRB (lowest frequency). The frequency offset may be previously provided from DU to RU, which

indicates the location of lowest resource element's centre in the lowest RB defined by frame structure, with respect to centre-of-channel-bandwidth.

[0122] In particular, some fields or information elements (IE)s in Format #1 are as follows:

- *Section Type X*: the type of the message is X which is to be defined.
- *msb*: the most significant bit.
- *lsb*: the least *significant* bit.
- *eCPRI transport header*: a header of the transport protocol conveying the SRS configuration based on eCPRI (enhanced Common Public Radio Interface).
- *dataDirection*: the data transmission direction of the base station.
- *payloadVersion*: a version of payload, indicating the valid payload protocol version of information elements in the application layer, and the channel between IQ data and air interface to be used in both DL and UL.
- *filterIndex*: an index of a filter (e.g. channel filter).
- *frameId*: an ID of a frame, indicating a frame number.
- *subframeId*: an ID of a sub-frame, indicating a subframe number.
- *slotId*: an ID of a slot, indicating a slot number.
- *numberOfsections*: a total number of sections.
- *ciCompHdr*: channel information compression header, indicating a compression method.
- *sectionId*: an ID of the section.
- *symInc*: a symbol number increment command.
- *startPrb*: an index of the starting PRB of the data section description, i.e., the initial PRB.
- *numPrb*: a total number of contiguous PRBs per data section description.

- *repetitionFactor*: a total number of repetitions for an SRS transmission occasion of the UE. The value of *repetitionFactor* can be 1, 2 or 4.
- *u*: sequence group, indicating the group that the SRS sequence belongs to.
- *v*: sequence number, indicating the SRS sequence ID within the sequence group.
- *ef*: section flag, indicating whether there is another section present or whether the current section field is the last section.
- *receptionCombType*: a total number of subcarriers on which the UE transmits SRS sequence each time. For example, the *receptionCombType* has the value of 2, 4 and 8, where value 2 indicates the UE transmits SRS sequence on every two subcarriers, value 4 indicates the UE transmits SRS sequence on every four subcarriers, and value 8 indicates the UE transmits SRS sequence on every eight subcarriers.
- *combOffset*: the subcarrier on which the UE transmits SRS sequence. The *combOffset* has the value range [0 ... 1] for the reception comb type 2, value range [0 ... 3] for the reception comb type 4, and value range [0 ... 7] for the reception comb type 8.
- *startSymbolId*, *numSymbol*, *periodicity* and *offset* are included in Format #1 to indicate the time domain information of the SRS configuration.
 - *startSymbolId* indicates the start position in the slot.
 - *numSymbol* indicates the number of symbols for the SRS sequence reception.
 - If *periodicity* is included, *offset* is for periodic and semi-persistent SRS. The *periodicity* indicates the periodicity of the SRS resource, given in number of slots. For each periodicity, the corresponding offset is given in number of slots.
 - If *periodicity* is not included, *offset* is for aperiodic SRS. The *offset* is the difference between the DCI triggering the SRS and the slot for the SRS sequence reception.
- *rb* and *reMask* are included to indicate the frequency domain information of the SRS configuration, where *rb* indicates the resource block ID, and *reMask* indicates the resource element mask within the corresponding resource block.

- *startRbIndexAndFreqScalingFactor* may be further included which is to be used to determine the length of the SRS sequence for partial frequency sounding.
- To support cyclic hopping and/or comb offset hopping:
 - The hopping finer granularity is given by *hoppingFinerGranularity*.
 - The time-domain hopping behaviour for repetition factor is given by *hoppingWithRepetition*.
 - The set of cyclic shifts or the set of comb offsets is given by *hoppingSubset*: if the *hoppingFinerGranularity* is include, the *hoppingSubset* indicates the set of cyclic shifts; otherwise, if the *hoppingWithRepetition* is included, the *hoppingSubset* indicates the set of comb offsets.
- *spatialRelationInfo* and *tciState* are included to indicate the spatial domain information of the SRS configuration.
 - *spatialRelationInfo* indicates the configuration of the spatial relation between a reference RS and the SRS, where the reference RS can be SSB or CSI-RS.
 - *tciState* indicates the configuration of either a UL TCI state or a joint TCI state for the SRS resource, where the TCI state associates one or two DL reference signals with a corresponding quasi-colocation type.

[0123] The SRS configuration may be associated one or multiple UEs, where each UE is associated with a corresponding cyclic shift. The *cyclicShift* indicates the total number of cyclic shifts for an antenna port, which as a value range corresponding to the comb type, and *ueId* indicates an ID of each UE, e.g. an ID the first UE, an ID the second UE (not shown in Format #1), ... and/or an ID the last UE. For example, the *cyclicShift* has the value range [0 ... 7] for the reception comb type 2 (i.e. *receptionCombType* = 2), value range [0 ... 11] for the reception comb type 4 (i.e. *receptionCombType* = 4), and value range [0 ... 5] for the reception comb type 8 (i.e. *receptionCombType* = 8).

Format #1

Section Type X: SRS configuration								
0 (msb)	1	2	3	4	5	6	7 (lsb)	number of bytes

eCPRI transport header				8
dataDirection	payloadVersion	filterIndex		1
frameId				1
subframeId		slotId		1
slotId	startSymbolId			1
numberOfSections				1
sectionType = x				1
ciCompHdr				1
reserved				1
sectionId				1
sectionId	rb	symInc	startPrb	1
startPrb				1
numPrb				1
reMask				1
reMask		numSymbol		1
repetitionFactor		periodicity	offset	1
startRbIndexAndFreqScaling Factor	receptionCombType	combOffset		1
hoppingFinerGranularity		hoppingWithRepetition		1
hoppingSubset				1
u			v	1
spatialRelationInfo				4
tciState				4
ef	ueId (first UE)			1
ueId (first UE)				1
cyclicShift				1

.....		
ef	ueId (last UE)	1
ueId (last UE)		1
cyclicShift		1

[0124] At 802 (optional), the RU may send an SRS configuration response or an SRS configuration failure to the DU. If the RU is capable to provide SRS channel information as requested by the DU or if the RU is capable to perform an SRS CE operation, the RU may respond with an SRS configuration response. If the RU is not capable to provide SRS channel information as requested by the DU or if the RU is not capable to perform an SRS CE operation, the RU may respond with an SRS configuration failure.

[0125] At 803 (as shown as 803A or 803B), the RU may receive one or more SRS sequences from a UE (and/or one or more other UEs not shown in Figure 8) after operation 801. In an example, as shown in Figure 8, the RU may receive one or more SRS sequences from the UE at 803A before operation 802. In another example, the RU may receive one or more SRS sequences from the UE at 803B after operation 802.

[0126] At 804, the RU may perform an SRS CE operation to determine SRS channel information based on the one or more SRS sequences received from the UE. For instance, based on the SRS configuration provided by the DU at 801, the RU receives the SRS sequences (SRS signal) from the UE at 803, and then calculates the SRS channel information for the UE-RU link at 804.

[0127] In one example, the SRS channel information includes SINR and/or "a TA value between the RU and the UE." The SINR and/or the TA value may be calculated based on each SRS resource reception occasion.

[0128] In another example, the SRS channel information includes the channel coefficients (in-phase quadrature (IQ) sample) for specific PRBs for an SRS resource reception occasion. For example, the SRS channel information can be the wideband channel coefficients for all the PRBs for the SRS resources, or the SRS channel information can be the sub-band channel coefficients for all the PRBs, wherein every two of four PRBs may have a set of channel coefficients.

[0129] At 805, the RU may report the SRS channel information by sending an SRS report to the DU. The SRS report may include the SRS channel information for the specific PRBs. For example, the SRS channel information includes the SINR and/or the TA value between the RU and the UE.

[0130] In some embodiments, an indicator is included in the SRS report at 805, to indicate the type of the SRS channel information. For example, the indicator includes 2 bits, where the value 01 indicates that the SINR is included, value 10 indicates that the TA value is included, and value 11 indicates that both the SINR and the TA value are included.

[0131] In some embodiments, the SRS report may further include the channel coefficients per PRB. In this case, an indicator may be included in the SRS report, to indicate that the channel coefficients are further included.

[0132] For example, the SRS report based on O-RAN LLS-C is shown in Format #2 as below, where a new section type (Section Type Y) is introduced to provide the SRS report from the RU to the DU. In O-RAN LLS-C, a section defines the characteristics of LLS-U data to be transferred or received from a beam with one pattern ID. Some fields or IEs in Format #2 are similar to those as describe above in Format #1. For example, *Section Type Y* means that the type of the message is Y which is to be defined. In particular, some fields or IEs in Format #2 are as follows:

- *startSymbolID* indicates the starting symbol used for the CE, i.e., the initial symbol.
- *numSymbol* indicates the number of symbols used for the CE.
- *startPrb* indicates the starting PRB used for the CE, i.e., the initial PRB.
- *numPrb* indicates the number of contiguous PRBs used for the CE.
- *reportType* indicates the type of CE included in the SRS Report. For example, value 01 indicates the SINR is included, value 10 indicates the TA value is included, and value 11 indicates both the SINR and the TA value are included.
- *mf* indicates the channel coefficients are further included in the SRS report.
- *channelEstimationReport* indicates channel estimation information of the corresponding UE, e.g. the SINR and/or the TA value.

[0133] If there are multiple UEs' reports, the SRS report may include the SRS channel information for multiple UEs (i.e. multiple CE reports), where each CE report is associated with one UE ID of these multiple UEs. In this case, the "mf" in the SRS report associated with the UE indicates whether the channel coefficients are further provided for the corresponding UE. For example, value 0 of mf indicates that no channel coefficient is further included in the SRS report, while value 1 of mf indicates that that one or more channel coefficients are further included in the SRS report.

Format #2

Section Type Y: SRS report								
0 (msb)	1	2	3	4	5	6	7 (lsb)	number of bytes
eCPRI Transport Header								8
dataDir ection	payloadVersion			reserved				1
frameId								1
subframeId				slotId				1
slotId		startSymbolId						1
numberOfSections								1
sectionType=Y								1
reserved								2
sectionId								1
sectionId				rb	reserved	startPrb		1
startPrb								1
numPrb								1
numSymbol				reserved				1
ef	ueId (of first UE)							1
ueId (of first UE)								1
reportType		mf	channelEstimationReport				variable	
Section Extensions for providing additional report as indicated by "mf" in previous report.								variable
...								
ef	ueId (of last UE)							1
ueId (of last UE)								1
reportType		mf	channelEstimationReport				variable	
Section Extensions for providing additional report as indicated by "mf" in previous report.								variable

[0134] If the channel coefficients are further included (i.e., the "mf" IE is set with value 1), a new section extension type (e.g. Section Extension M as below) (i.e. the IE of "Section Extensions for providing additional report as indicated by 'mf' in previous report") may be introduced in the Section Type Y (i.e. the SRS report), to provide the channel coefficients per PRB from the RU to the DU. In O-RAN LLS-C, a section extension includes the parameters that apply to the Section Type Y beyond those within the Section Type Y.

[0135] For example, the channel coefficients may be provided per PRB and per antenna in Section Extension M. Section Extension M may include IQ samples per antenna of each PRB, e.g. ciIsample and ciQsample as below.

Section Extension M

0 (msb)	1	2	3	4	5	6	7 (lsb)	number of bytes
ciIsample (first PRB, first antenna)								variable
ciQsample (first PRB, first antenna)								variable
ciIsample (first PRB, second antenna)								variable
ciQsample (first PRB, second antenna)								variable
...								
ciIsample (first PRB, last antenna)								variable
ciQsample (first PRB, last antenna)								variable
ciIsample (second PRB, first antenna)								
ciQsample (second PRB, first antenna)								
...								
ciIsample (last PRB, last antenna)								variable
ciQsample (last PRB, last antenna)								variable

[0136] **Embodiment #2**

[0137] Embodiment #2 provides solutions for non-contiguous PRB channel report by a RU, where the RU can report a part of PRB's channel coefficients but not all PRBs in order to reduce the traffic over the LLS interface.

[0138] Operations 801, 802, 803 and 804 in Embodiment #2 are the same as the operations 801, 802, 803 and 804 in Embodiment #1.

[0139] At 805, the RU may report the SRS channel information for the UE by sending an SRS report to the DU. The detailed description of the SRS report shown in Format #2 of Embodiment #1 as described above may be applicable here in Embodiment #2.

[0140] To support the non-contiguous PRB channel report, the following two solutions are supported in Embodiment #2.

[0141] Solution #1: If one or more PRBs are not used for the SRS CE, the RU provides the channel coefficients of the one or more PRBs (e.g. Section Extension M as shown above) with a default value, e.g. value 0. For example, in Section Extension M conveying the channel coefficients per PRB, the channel coefficients are set to value 0. On receipt of the channel coefficients with value 0, the DU may determine that the corresponding one or more PRBs are not used for the SRS CE.

[0142] For example, in Section Extension M as shown above, if the channel coefficients of four PRBs are included, and if ci_{Isample} and ci_{Qsample} of the second and third PRBs are set to value 0, while ci_{Isample} and ci_{Qsample} of the first and fourth PRBs are not set to value 0, the DU can determine that the second and third PRBs are not used for the SRS CE.

[0143] Solution #2: A new section extension type (e.g. Section Extension P as below) (i.e. the IE of "Section Extensions for providing additional report as indicated by '*mf*' in previous report") is included in the SRS report (i.e. Section Type Y), to provide one or more PRBs that are not used for the SRS CE. For example, Section Extension P includes the following fields or IEs.

- *offStartPrb* indicates the starting PRB (i.e., the first or initial PRB) within the contiguous PRBs that is not used for the SRS CE.
- *numOffStartPrb* indicates the total number of PRBs within the contiguous PRBs that are not used for the SRS CE.

Section Extension P

0 (msb)	1	2	3	4	5	6	7 (lsb)	number of bytes	
offStartPrb								1	variable
numOffStartPrb								1	variable
...									
offStartPrb								1	variable
numOffStartPrb								1	variable

[0144] On receipt of Section Extension P in the SRS report (i.e. Section Type Y), the DU may determine that the corresponding PRBs are not used for the SRS CE. The total line number of Section Extension P may be varied due to different total number of PRBs according to different embodiments.

[0145] For example, if there are four lines in Section Extension P, which includes two sets of "*offStartPrb* and *numOffStartPrb*", and if *offStartPrb* = PRB #5 and *numOffStartPrb* = 3 in the first and second lines, the DU can determine that PRB #5, PRB #6 and PRB #7 within the contiguous PRBs are not used for the SRS CE for the corresponding UE. If *offStartPrb* = PRB #10 and *numOffStartPrb* = 1 in the third and fourth lines, the DU can determine that PRB #10 within the contiguous PRBs is not used for the SRS CE for the corresponding UE.

[0146] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed:

1. A first base station (BS), comprising:
 - at least one memory; and
 - at least one processor coupled to the at least one memory and configured to cause the first BS to:
 - generate a sounding reference signal (SRS) configuration for at least one user equipment (UE); and
 - transmit the SRS configuration to a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the second BS to perform an SRS channel estimation (CE) operation for the at least one UE.
2. The first BS of Claim 1, wherein the SRS configuration defines at least one SRS resource, and the at least one SRS resource is used by the at least one UE to generate at least one SRS sequence.
3. The first BS of Claim 2, wherein a first SRS resource within the at least one SRS resource is used by two or more UEs within the at least one UE to generate two or more SRS sequences.
4. The first BS of Claim 2, wherein the at least one SRS resource includes time domain related information, and the time domain related information includes at least one of the following:
 - a starting symbol in a time slot;
 - a total number of symbols for an SRS sequence transmission of the at least one UE;
 - a total number of repetitions for an SRS transmission occasion of the at least one UE;
 - a periodicity of the at least one SRS resource, and an offset corresponding to the periodicity for a periodic and semi-persistent SRS, wherein the periodicity and the offset are given in a total number of slots; or
 - an offset between downlink control information (DCI) triggering an SRS transmission by the at least one UE and a slot for a reception of an SRS sequence, if the at least one SRS resource is associated with an aperiodic SRS.

5. The first BS of Claim 2, wherein the at least one SRS resource includes frequency domain related information, and the frequency domain related information includes at least one of the following:
 - an identifier (ID) of a resource block;
 - a resource element mask within the resource block; or
 - information used to determine a length of an SRS sequence for a partial frequency sounding, and the SRS sequence is generated by the UE based on the at least one SRS resource.
6. The first BS of Claim 2, wherein the at least one SRS resource includes at least one of the following:
 - hopping finer granularity enabling finer granular hopping, and a set of cyclic shifts, if the SRS configuration is associated with cyclic shift hopping;
 - a time-domain behaviour for a total number of repetitions for an SRS transmission occasion of the at least one UE, and a set of comb offsets, if the at least one SRS resource is associated with comb offset hopping; or
 - a total number of one or more cyclic shifts for an antenna port, where a cyclic shift within the one or more cyclic shifts is associated with an identifier (ID) of the at least one UE.
7. The first BS of Claim 2, wherein the at least one SRS resource includes spatial domain related information, and the spatial domain related information includes at least one of the following:
 - a configuration of spatial relation between a reference reference-signal (RS) and an SRS; or
 - a configuration of a transmission configuration indicator (TCI) state of the at least one SRS resource.
8. The first BS of Claim 7, wherein the TCI state associates one or two downlink (DL) reference signals with a quasi-colocation type.
9. The first BS of Claim 1, wherein the at least one processor is configured to cause the first BS to receive first information from the second BS, and the first information indicates at least one of the following:

the second BS is capable to perform the SRS channel estimation operation; or
the second BS is not capable to perform the SRS channel estimation operation.

10. The first BS of Claim 1, wherein the at least one processor is configured to cause the first BS to receive SRS channel information for the at least one UE from the second BS over the LLS interface.
11. The first BS of Claim 10, wherein the SRS channel information includes at least one of the following:
 - a signal to interference plus noise ratio (SINR);
 - a timing advance (TA) value between the second BS and the at least one UE; or
 - one or more channel coefficients per physical resource block (PRB).
12. The first BS of Claim 11, wherein the at least one processor is configured to cause the first BS to perform at least one of the following:
 - considering that one or more PRBs are not used for the SRS CE operation, if the one or more channel coefficients for the one or more PRBs are set as a default value; or
 - determining, from the SRS channel information, ID information of a starting PRB within each set of one or more sets of contiguous PRBs and a total PRB number of the each set of the one or more sets of contiguous PRBs, and consider that the one or more sets of contiguous PRBs are not used for the SRS CE operation.
13. The first BS of any of Claims 1-12, wherein at least one of the SRS configuration or the SRS channel information is carried in a section type message over the LLS interface.
14. The first BS of Claim 13, wherein if the SRS channel information is carried in the section type message, the section type message includes at least one of the following:
 - a first indicator for indicating a type of the SRS channel information;
 - a second indicator for indicating that the one or more channel coefficients per PRB are included in the section type message;
 - a first section extension including the one or more channel coefficients per PRB;
 - a second section extension indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation; or

a third indicator for indicating one or more sets of contiguous PRBs that are not used for the SRS CE operation.

15. The first BS of any of Claims 1-14, wherein the first BS is a distributed unit (DU) hosting high physical layers, and the second BS is a radio unit (RU) hosting low physical layers.
16. A first base station (BS), comprising:
 - at least one memory; and
 - at least one processor coupled to the at least one memory and configured to cause the first BS to:
 - receive a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the first BS to perform an SRS channel estimation (CE) operation for the at least one UE;
 - receive an SRS sequence from the at least one UE; and
 - perform the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.
17. The first BS of Claim 16, wherein the SRS configuration defines at least one SRS resource, and the at least one SRS resource is used by the at least one UE to generate at least one SRS sequence.
18. The first BS of Claim 17, wherein a first SRS resource within the at least one SRS resource is used by two or more UEs within the at least one UE to generate two or more SRS sequences.
19. A method performed by a first base station (BS), comprising:
 - generating a sounding reference signal (SRS) configuration for at least one user equipment (UE); and
 - transmitting the SRS configuration to a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the second BS to perform an SRS channel estimation (CE) operation for the at least one UE.

20. A method performed by a first base station (BS), comprising:

receiving a sounding reference signal (SRS) configuration for at least one user equipment (UE) from a second BS over an lower layer split (LLS) interface between the first BS and the second BS, wherein the SRS configuration is used by the first BS to perform an SRS channel estimation (CE) operation for the at least one UE;

receiving an SRS sequence from the at least one UE; and

performing the SRS CE operation based on the received SRS sequence to determine SRS channel information for the at least one UE.

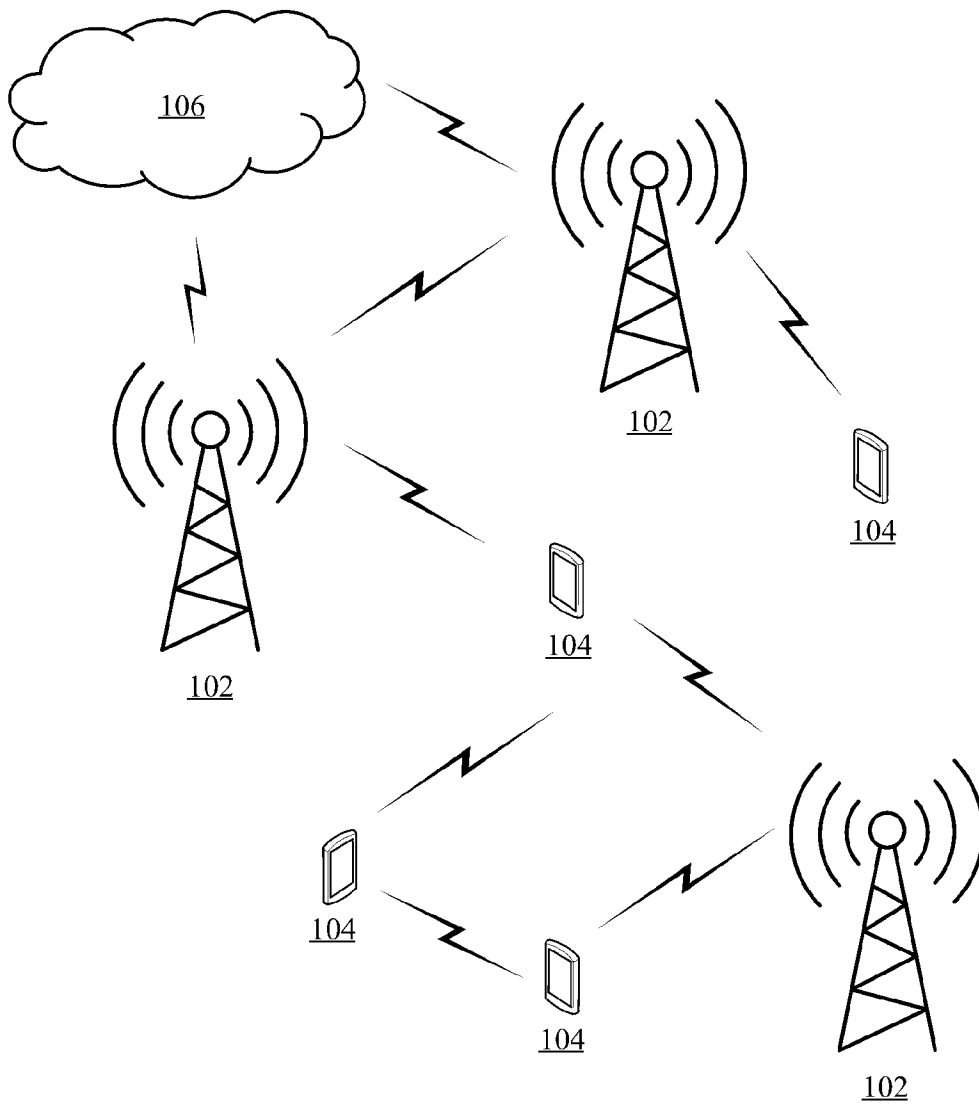


Figure 1

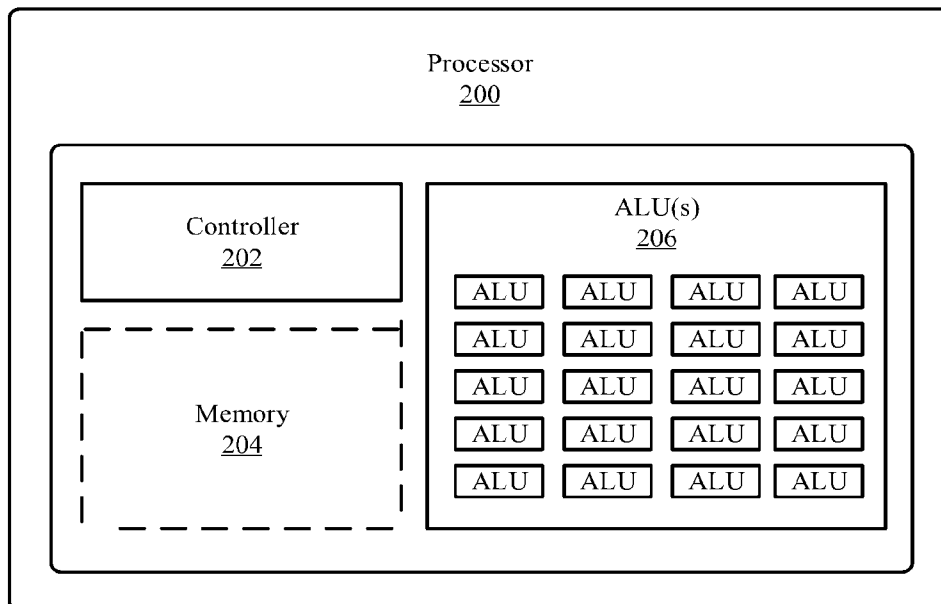


Figure 2

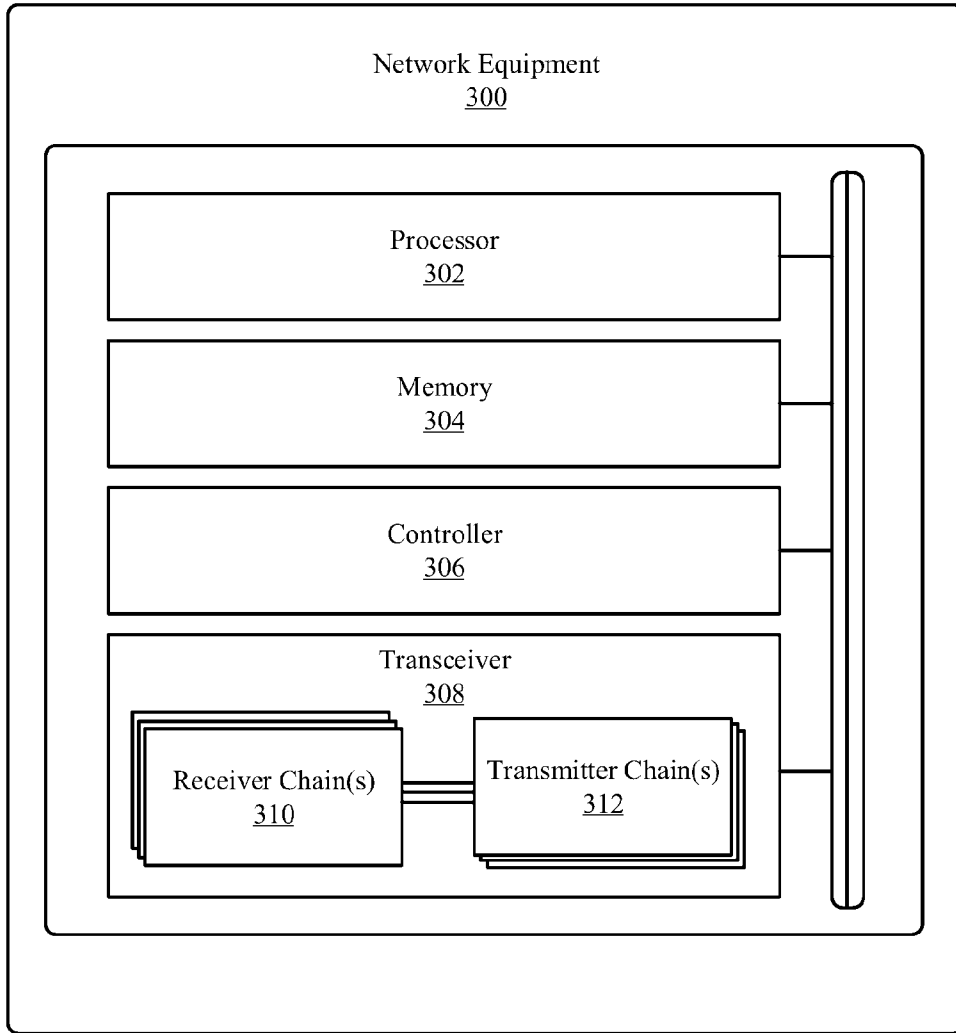


Figure 3

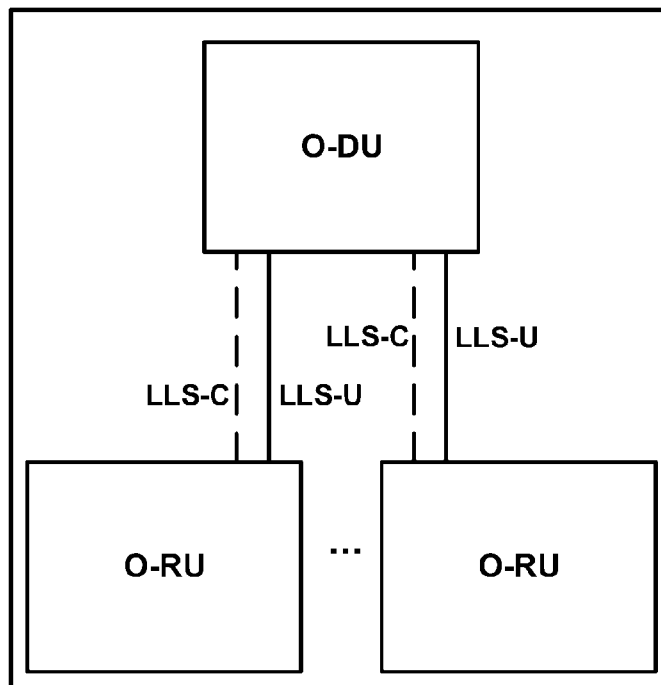


Figure 4

in O-DU in O-RU

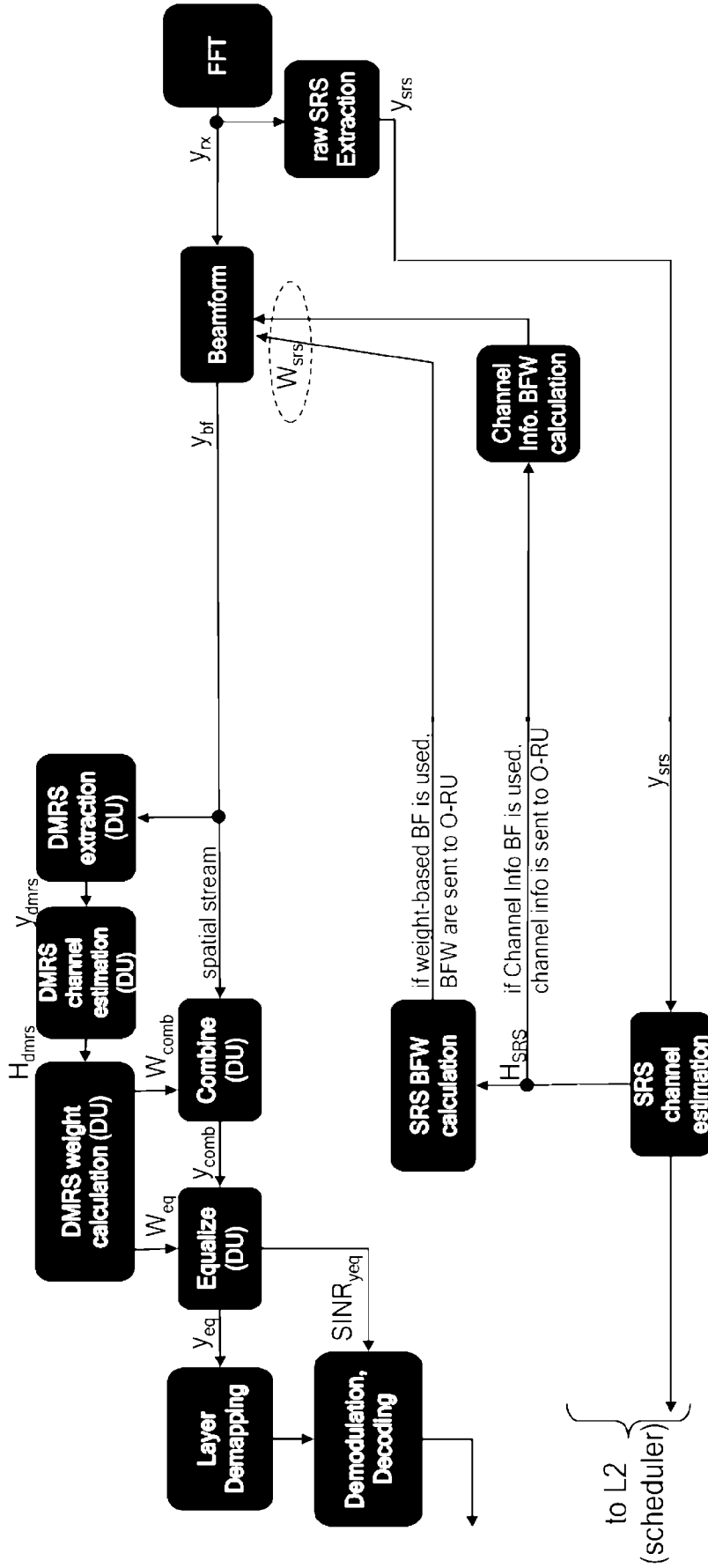


Figure 5

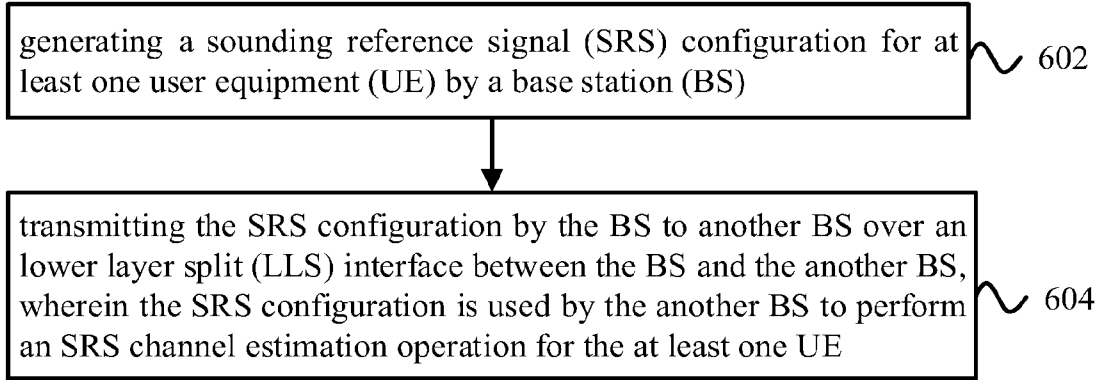


Figure 6

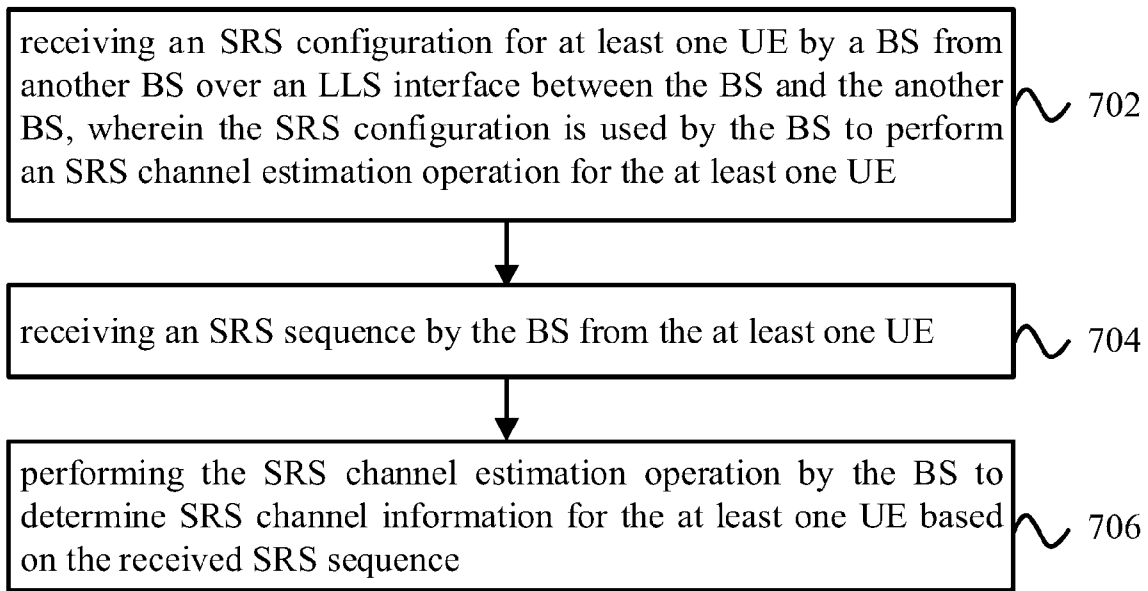


Figure 7

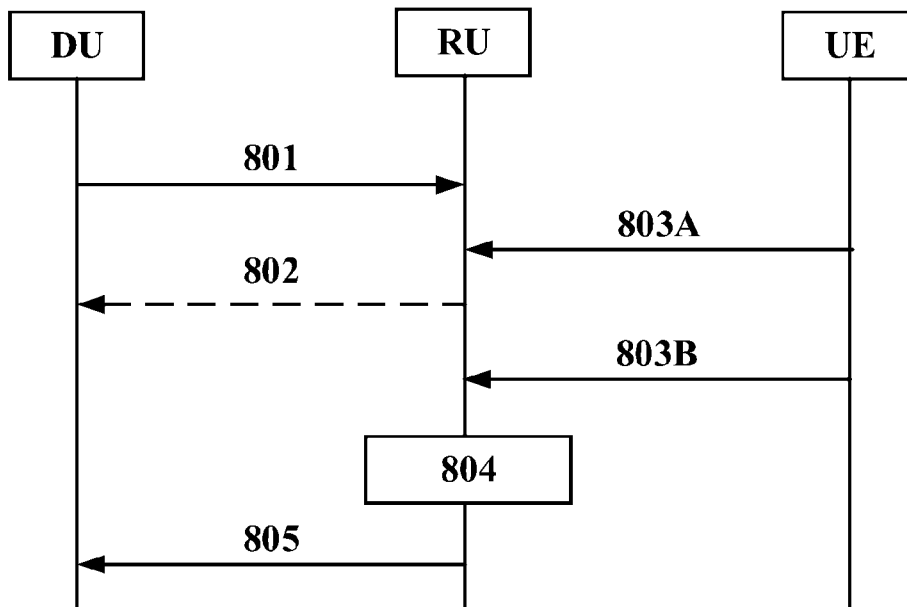


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/113302

A. CLASSIFICATION OF SUBJECT MATTER H04B17/309(2015.01)i; H04W92/20(2009.01)n 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; H04W; H04L 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) CNTXT;CNKI;ENTXTC;ENTXT;DWPI;IEEE;3GPP: channel estimation, sounding reference signal, sequence, configuration, radio unit, low layer split, DU, RU, SRS, SINR, LLS, CE		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2024025172 A1 (SAMSUNG ELECTRONICS CO LTD) 01 February 2024 (2024-02-01) description, paragraphs 39-258 and figures 5-12	1-20
X	WO 2023249356 A1 (SAMSUNG ELECTRONICS CO LTD) 28 December 2023 (2023-12-28) description, paragraphs 50-183 and figure 7	1-20
A	WO 2024161343 A1 (ERICSSON TELEFON AB L M) 08 August 2024 (2024-08-08) the whole document	1-20
A	US 2023344474 A1 (AT & T IP ILP) 26 October 2023 (2023-10-26) the whole document	1-20
A	KR 101674315 B1 (UNIV SEOUL NAT R & DB FOUND) 08 November 2016 (2016-11-08) the whole document	1-20
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Date of the actual completion of the international search 07 May 2025		Date of mailing of the international search report 08 May 2025
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

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