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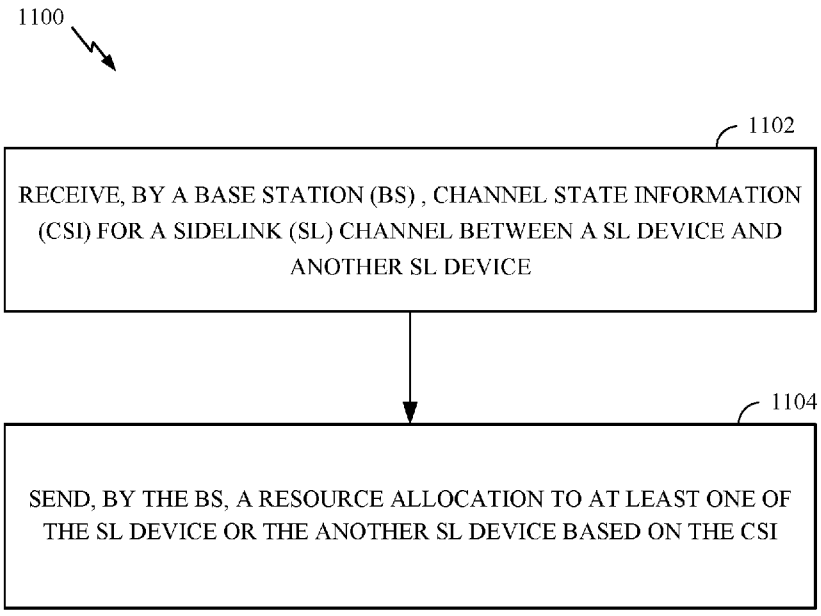


FIG. 11

(57) Abstract: Certain aspects of the present disclosure provide techniques for channel state information (CSI) forwarding in sidelink (SL). In certain aspects, a method performed by a SL device generally includes determining channel state information (CSI) for a SL channel between the SL device and another SL device, and transmitting the CSI to a base station (BS). In certain aspects, a method performed by a BS generally includes receiving CSI for a SL channel between a SL device and another SL device, and sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.

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CSI FORWARDING IN SIDELINK

BACKGROUND

Field of the Disclosure

[0001] Aspects of the present disclosure relate to wireless communications, and more particularly, to techniques for sidelink channel state information (CSI) forwarding.

Description of Related Art

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, broadcasts, etc. These wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power, etc.). Examples of such multiple-access systems include 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) systems, LTE Advanced (LTE-A) systems, code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems, to name a few.

[0003] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. New radio (e.g., 5G NR) is an example of an emerging telecommunication standard. NR is a set of enhancements to the LTE mobile standard promulgated by 3GPP. NR is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA with a cyclic prefix (CP) on the downlink (DL) and on the uplink (UL). To these ends, NR supports beamforming, multiple-input multiple-output (MIMO) antenna technology, and carrier aggregation.

[0004] However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in NR and LTE technology. Preferably, these

improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0005] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of this disclosure provide advantages that include improved resource allocation in sidelink communication.

[0006] Certain aspects of the subject matter described in this disclosure can be implemented in a method for wireless communication by a sidelink (SL) device. The method generally includes determining channel state information (CSI) for a SL channel between the SL device and another SL device. The method generally includes transmitting the CSI to a base station (BS).

[0007] Certain aspects of the subject matter described in this disclosure can be implemented in a method for wireless communication by a base station (BS). The method generally includes receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device. The method generally includes sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.

[0008] Certain aspects of the subject matter described in this disclosure can be implemented in an apparatus for wireless communications. The apparatus generally includes a processing system configured to determine channel state information (CSI) for a SL channel between the SL device and another SL device. The processing system is configured to transmit the CSI to a base station (BS).

[0009] Certain aspects of the subject matter described in this disclosure can be implemented in an apparatus for wireless communications. The apparatus generally includes a processing system configured to receive channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device. The processing system

is configured to send a resource allocation to at least one of the SL device or the another SL device based on the CSI.

[0010] Certain aspects of the subject matter described in this disclosure can be implemented in an apparatus for wireless communications. The apparatus generally includes means for determining channel state information (CSI) for a SL channel between the SL device and another SL device. The apparatus generally includes means for transmitting the CSI to a base station (BS).

[0011] Certain aspects of the subject matter described in this disclosure can be implemented in an apparatus for wireless communications. The apparatus generally includes means for receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device. The apparatus generally includes means for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.

[0012] Certain aspects of the subject matter described in this disclosure can be implemented in a non-transitory computer-readable medium for wireless communications. The non-transitory computer-readable medium generally includes instructions executable to determine channel state information (CSI) for a SL channel between the SL device and another SL device. The non-transitory computer-readable medium generally includes instructions executable to transmit the CSI to a base station (BS).

[0013] Certain aspects of the subject matter described in this disclosure can be implemented in a non-transitory computer-readable medium for wireless communications. The non-transitory computer-readable medium generally includes instructions executable to receive channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device. The non-transitory computer-readable medium generally includes instructions executable to send a resource allocation to at least one of the SL device or the another SL device based on the CSI.

[0014] Aspects of the present disclosure provide means for, apparatus, processors, and computer-readable mediums for performing the methods described herein.

[0015] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the appended drawings set forth in detail certain

illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0017] **FIG. 1** is a block diagram conceptually illustrating an example wireless communication network, in accordance with certain aspects of the present disclosure.

[0018] **FIG. 2** is a block diagram conceptually illustrating a design of an example a base station (BS) and user equipment (UE), in accordance with certain aspects of the present disclosure.

[0019] **FIG. 3** is an example frame format for certain wireless communication systems (e.g., new radio (NR)), in accordance with certain aspects of the present disclosure.

[0020] **FIG. 4A** and **FIG. 4B** show diagrammatic representations of example vehicle to everything (V2X) systems, in accordance with certain aspects of the present disclosure.

[0021] **FIG. 5** is a call flow diagram illustrating example resource allocation for sidelink transmission, in accordance with certain aspects of the present disclosure.

[0022] **FIG. 6** is a call flow diagram illustrating example autonomous resource selection for sidelink transmission, in accordance with certain aspects of the present disclosure.

[0023] **FIG. 7** is a flow diagram illustrating example operations for wireless communication by a sidelink device, in accordance with certain aspects of the present disclosure.

[0024] **FIG. 8** is a call flow diagram illustrating example channel state information (CSI) forwarding by a transmitting sidelink device, in accordance with aspects of the present disclosure.

[0025] **FIG. 9** is a bit layout of example information to be forwarded by a UE in sidelink, in accordance with aspects of the present disclosure.

[0026] **FIG. 10** is another call flow diagram illustrating example CSI forwarding from a receiving sidelink device, in accordance with aspects of the present disclosure.

[0027] **FIG. 11** is a flow diagram illustrating example operations for wireless communication by a BS, in accordance with certain aspects of the present disclosure.

[0028] **FIG. 12** illustrates a communications device that may include various components configured to perform operations for the techniques disclosed herein in accordance with aspects of the present disclosure.

[0029] **FIG. 13** illustrates a communications device that may include various components configured to perform operations for the techniques disclosed herein in accordance with aspects of the present disclosure.

[0030] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one aspect may be beneficially utilized on other aspects without specific recitation.

DETAILED DESCRIPTION

[0031] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for forwarding channel state information (CSI) in sidelink communication. In particular, certain aspects of the present disclosure provide advantages for resource allocation, such as enabling spatial multiplexing, by forwarding CSI to a base station (BS).

[0032] A BS may have no knowledge of CSI, rank, and/or other sidelink scheduling information, since a transmitting sidelink device may not provide such scheduling information. Consequently, scheduling, by the BS, of SL spatial multiplexing of transmissions may be challenging and prone to interference, as described herein with respect to **FIG. 5**.

[0033] Accordingly, certain aspects of the present disclosure provides techniques and apparatus for forwarding sidelink CSI to a BS. In some examples, CSI may be determined by a sidelink (SL) device for a channel between the SL device and another SL device. In

some examples, the CSI may be transmitted to the BS. In some examples, the CSI may be forwarded to the BS by a transmitting UE when a receiving UE belongs to another cell. In some examples, the CSI may be forwarded to the BS by the receiving UE when the receiving UE belongs to the same cell as the transmitting UE. In some examples, the CSI may be sent by multiple UEs to the transmitting UE. In some examples, the CSI may be sent via uplink control information (UCI), medium access control (MAC) control element (CE), or cellular interface (Uu).

[0034] The following description provides examples of CSI forwarding in sidelink communication systems, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in some other examples. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to, or other than, the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim. The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects.

[0035] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular radio access technology (RAT) and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a subcarrier, a frequency channel, a tone, a subband, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs.

[0036] The techniques described herein may be used for various wireless networks and radio technologies. While aspects may be described herein using terminology commonly associated with 3G, 4G, and/or new radio (e.g., 5G NR) wireless technologies, aspects of the present disclosure can be applied in other generation-based communication systems.

[0037] NR access may support various wireless communication services, such as enhanced mobile broadband (eMBB) targeting wide bandwidth (e.g., 80 MHz or beyond), millimeter wave (mmW) targeting high carrier frequency (e.g., e.g., 24 GHz to 53 GHz or beyond), massive machine type communications MTC (mMTC) targeting non-backward compatible MTC techniques, and/or mission critical targeting ultra-reliable low-latency communications (URLLC). These services may include latency and reliability requirements. These services may also have different transmission time intervals (TTI) to meet respective quality of service (QoS) requirements. In addition, these services may co-exist in the same subframe. NR supports beamforming and beam direction may be dynamically configured. MIMO transmissions with precoding may also be supported. MIMO configurations in the DL may support up to 8 transmit antennas with multi-layer DL transmissions up to 8 streams and up to 2 streams per UE. Multi-layer transmissions with up to 2 streams per UE may be supported. Aggregation of multiple cells may be supported with up to 8 serving cells.

[0038] **FIG. 1** illustrates an example wireless communication network 100 in which aspects of the present disclosure may be performed. For example, the wireless communication network 100 may be an NR system (e.g., a 5G NR network). As shown in **FIG. 1**, the wireless communication network 100 may be in communication with a core network 132. The core network 132 may be in communication with one or more BSs 110 and/or UEs 120 in the wireless communication network 100 via one or more interfaces.

[0039] According to certain aspects, the BSs 110 and UEs 120 may be configured for forwarding sidelink CSI to a BS. As shown in **FIG. 1**, the BS 110a includes a resource manager 112 that allocates resources based at least in part on received CSI, in accordance with aspects of the present disclosure. The UEs 120a, 120b, 120c include a resource manager 122a, 122b, and 122c, respectively, that may be configured for forwarding

sidelink CSI to a BS (e.g., the BS 110), in accordance with aspects of the present disclosure.

[0040] As illustrated in **FIG. 1**, the wireless communication network 100 may include a number of BSs 110a-z (each also individually referred to herein as BS 110 or collectively as BSs 110) and other network entities. A BS 110 may provide communication coverage for a particular geographic area, sometimes referred to as a "cell", which may be stationary or may move according to the location of a mobile BS 110. In some examples, the BSs 110 may be interconnected to one another and/or to one or more other BSs or network nodes (not shown) in wireless communication network 100 through various types of backhaul interfaces (e.g., a direct physical connection, a wireless connection, a virtual network, or the like) using any suitable transport network. In the example shown in **FIG. 1**, the BSs 110a, 110b and 110c may be macro BSs for the macro cells 102a, 102b and 102c, respectively. The BS 110x may be a pico BS for a pico cell 102x. The BSs 110y and 110z may be femto BSs for the femto cells 102y and 102z, respectively. A BS may support one or multiple cells.

[0041] The BSs 110 communicate with UEs 120a-y (each also individually referred to herein as UE 120 or collectively as UEs 120) in the wireless communication network 100. The UEs 120 (e.g., 120x, 120y, etc.) may be dispersed throughout the wireless communication network 100, and each UE 120 may be stationary or mobile. Wireless communication network 100 may also include relay stations (e.g., relay station 110r), also referred to as relays or the like, that receive a transmission of data and/or other information from an upstream station (e.g., a BS 110a or a UE 120r) and sends a transmission of the data and/or other information to a downstream station (e.g., a UE 120 or a BS 110), or that relays transmissions between UEs 120, to facilitate communication between devices.

[0042] A network controller 130 may be in communication with a set of BSs 110 and provide coordination and control for these BSs 110 (e.g., via a backhaul). In aspects, the network controller 130 may be in communication with a core network 132 (e.g., a 5G Core Network (5GC)), which provides various network functions such as Access and Mobility Management, Session Management, User Plane Function, Policy Control Function, Authentication Server Function, Unified Data Management, Application

Function, Network Exposure Function, Network Repository Function, Network Slice Selection Function, etc.

[0043] **FIG. 2** illustrates example components of BS 110a and UE 120a (e.g., which could also be a UE 120b or UE 120c), which may be used to implement aspects of the present disclosure.

[0044] At the BS 110a, a transmit processor 220 may receive data from a data source 212 and control information from a controller/processor 240. The control information may be for the physical broadcast channel (PBCH), physical control format indicator channel (PCFICH), physical hybrid ARQ indicator channel (PHICH), physical downlink control channel (PDCCH), group common PDCCH (GC PDCCH), etc. The data may be for the physical downlink shared channel (PDSCH), etc. A medium access control (MAC)-control element (MAC-CE) is a MAC layer communication structure that may be used for control command exchange between wireless nodes. The MAC-CE may be carried in a shared channel such as a physical downlink shared channel (PDSCH), a physical uplink shared channel (PUSCH), or a physical sidelink shared channel (PSSCH).

[0045] The processor 220 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The transmit processor 220 may also generate reference symbols, such as for the primary synchronization signal (PSS), secondary synchronization signal (SSS), PBCH demodulation reference signal (DMRS), and channel state information reference signal (CSI-RS). A transmit (TX) multiple-input multiple-output (MIMO) processor 230 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the reference symbols, if applicable, and may provide output symbol streams to the modulators (MODs) 232a-232t. Each modulator 232 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each modulator may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. Downlink signals from modulators 232a-232t may be transmitted via the antennas 234a-234t, respectively.

[0046] At the UE 120a, the antennas 252a-252r may receive the downlink signals from the BS 110a and may provide received signals to the demodulators (DEMODs) in transceivers 254a-254r, respectively. Each demodulator 254 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples.

Each demodulator may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A MIMO detector 256 may obtain received symbols from all the demodulators 254a-254r, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A receive processor 258 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded data for the UE 120a to a data sink 260, and provide decoded control information to a controller/processor 280.

[0047] On the uplink, at UE 120a, a transmit processor 264 may receive and process data (e.g., for the physical uplink shared channel (PUSCH)) from a data source 262 and control information (e.g., for the physical uplink control channel (PUCCH) from the controller/processor 280. The transmit processor 264 may also generate reference symbols for a reference signal (e.g., for the sounding reference signal (SRS)). The symbols from the transmit processor 264 may be precoded by a TX MIMO processor 266 if applicable, further processed by the modulators in transceivers 254a-254r (e.g., for SC-FDM, etc.), and transmitted to the BS 110a. At the BS 110a, the uplink signals from the UE 120a may be received by the antennas 234, processed by the demodulators 232, detected by a MIMO detector 236 if applicable, and further processed by a receive processor 238 to obtain decoded data and control information sent by the UE 120a. The receive processor 238 may provide the decoded data to a data sink 239 and the decoded control information to the controller/processor 240.

[0048] The memories 242 and 282 may store data and program codes for BS 110a and UE 120a, respectively. A scheduler 244 may schedule UEs for data transmission on the downlink and/or uplink.

[0049] Antennas 252, processors 266, 258, 264, and/or controller/processor 280 of the UE 120a and/or antennas 234, processors 220, 230, 238, and/or controller/processor 240 of the BS 110a may be used to perform the various techniques and methods described herein. For example, as shown in **FIG. 2**, the controller/processor 240 of the BS 110a has a resource manager 241 that allocates resources based on forwarded CSI, according to aspects described herein. As shown in **FIG. 2**, the controller/processor 280 of the UE 120a has a resource manager 281 that may be configured for receiver side protection in sidelink, according to aspects described herein. Although shown at the controller/processor, other components of the UE 120a and BS 110a may be used to perform the operations described herein.

[0050] NR may utilize orthogonal frequency division multiplexing (OFDM) with a cyclic prefix (CP) on the uplink and downlink. NR may support half-duplex operation using time division duplexing (TDD). OFDM and single-carrier frequency division multiplexing (SC-FDM) partition the system bandwidth into multiple orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. Modulation symbols may be sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers may be dependent on the system bandwidth. The minimum resource allocation, called a resource block (RB), may be 12 consecutive subcarriers. The system bandwidth may also be partitioned into subbands. For example, a subband may cover multiple RBs. NR may support a base subcarrier spacing (SCS) of 15 KHz and other SCS may be defined with respect to the base SCS (e.g., 30 kHz, 60 kHz, 120 kHz, 240 kHz, etc.).

[0051] **FIG. 3** is a diagram showing an example of a frame format 300 for NR. The transmission timeline for each of the downlink and uplink may be partitioned into units of radio frames. Each radio frame may have a predetermined duration (e.g., 10 ms) and may be partitioned into 10 subframes, each of 1 ms, with indices of 0 through 9. Each subframe may include a variable number of slots (e.g., 1, 2, 4, 8, 16, ... slots) depending on the SCS. Each slot may include a variable number of symbol periods (e.g., 7, 12, or 14 symbols) depending on the SCS. The symbol periods in each slot may be assigned indices. A mini-slot, which may be referred to as a sub-slot structure, refers to a transmit time interval having a duration less than a slot (e.g., 2, 3, or 4 symbols). Each symbol in a slot may indicate a link direction (e.g., DL, UL, or flexible) for data transmission and the link direction for each subframe may be dynamically switched. The link directions may be based on the slot format. Each slot may include DL/UL data as well as DL/UL control information.

[0052] In NR, a synchronization signal block (SSB) is transmitted. In certain aspects, SSBs may be transmitted in a burst where each SSB in the burst corresponds to a different beam direction for UE-side beam management (e.g., including beam selection and/or beam refinement). The SSB includes a PSS, a SSS, and a two symbol PBCH. The SSB can be transmitted in a fixed slot location, such as the symbols 0-3 as shown in **FIG. 3**. The PSS and SSS may be used by UEs for cell search and acquisition. The PSS may provide half-frame timing, the SS may provide the CP length and frame timing. The PSS

and SSS may provide the cell identity. The PBCH carries some basic system information, such as downlink system bandwidth, timing information within radio frame, SS burst set periodicity, system frame number, etc. The SSBs may be organized into SS bursts to support beam sweeping. Further system information such as, remaining minimum system information (RMSI), system information blocks (SIBs), other system information (OSI) can be transmitted on a physical downlink shared channel (PDSCH) in certain subframes. The SSB can be transmitted up to sixty-four times, for example, with up to sixty-four different beam directions for mmWave. The multiple transmissions of the SSB are referred to as a SS burst set. SSBs in an SS burst set may be transmitted in the same frequency region, while SSBs in different SS bursts sets can be transmitted at different frequency regions.

[0053] In some examples, the communication between the UEs 120 and BSs 110 is referred to as the access link. The access link may be provided via a Uu interface. Communication between devices may be referred as the sidelink.

[0054] In some examples, two or more subordinate entities (e.g., UEs 120) may communicate with each other using sidelink signals. Real-world applications of such sidelink communications may include public safety, proximity services, UE-to-network relaying, vehicle-to-vehicle (V2V) communications, Internet of Everything (IoE) communications, IoT communications, mission-critical mesh, and/or various other suitable applications. Generally, a sidelink signal may refer to a signal communicated from one subordinate entity (e.g., UE 120a) to another subordinate entity (e.g., another UE 120) without relaying that communication through the scheduling entity (e.g., UE 120 or BS 110), even though the scheduling entity may be utilized for scheduling and/or control purposes. In some examples, the sidelink signals may be communicated using a licensed spectrum (unlike wireless local area networks, which typically use an unlicensed spectrum). One example of sidelink communication is PC5, for example, as used in V2V, LTE, and/or NR.

[0055] Various sidelink channels may be used for sidelink communications, including a physical sidelink discovery channel (PSDCH), a physical sidelink control channel (PSCCH), a physical sidelink shared channel (PSSCH), and a physical sidelink feedback channel (PSFCH). The PSDCH may carry discovery expressions that enable proximal devices to discover each other. The PSCCH may carry control signaling such as

sidelink resource configurations and other parameters used for data transmissions, and the PSSCH may carry the data transmissions. The PSFCH may carry feedback such as CSI related to a sidelink channel quality.

[0056] **FIG. 4A** and **FIG. 4B** show diagrammatic representations of example V2X systems, in accordance with some aspects of the present disclosure. For example, the vehicles shown in **FIG. 4A** and **FIG. 4B** may communicate via sidelink channels and may perform sidelink CSI reporting as described herein.

[0057] The V2X systems, provided in **FIG. 4A** and **FIG. 4B** provide two complementary transmission modes. A first transmission mode, shown by way of example in **FIG. 4A**, involves direct communications (for example, also referred to as sidelink communications) between participants in proximity to one another in a local area. A second transmission mode, shown by way of example in **FIG. 4B**, involves network communications through a network, which may be implemented over a Uu interface (for example, a wireless communication interface between a radio access network (RAN) and a UE).

[0058] Referring to **FIG. 4A**, a V2X system 400 (for example, including vehicle to vehicle (V2V) communications) is illustrated with two vehicles 402, 404. The first transmission mode allows for direct communication between different participants in a given geographic location. As illustrated, a vehicle can have a wireless communication link 406 with an individual (V2P) (for example, via a UE) through a PC5 interface. Communications between the vehicles 402 and 404 may also occur through a PC5 interface 408. In a like manner, communication may occur from a vehicle 402 to other highway components (for example, highway component 410), such as a traffic signal or sign (V2I) through a PC5 interface 412. With respect to each communication link illustrated in **FIG. 4A**, two-way communication may take place between elements, therefore each element may be a transmitter and a receiver of information. The V2X system 400 may be a self-managed system implemented without assistance from a network entity. A self-managed system may enable improved spectral efficiency, reduced cost, and increased reliability as network service interruptions do not occur during handover operations for moving vehicles. The V2X system may be configured to operate in a licensed or unlicensed spectrum, thus any vehicle with an equipped system may

access a common frequency and share information. Such harmonized/common spectrum operations allow for safe and reliable operation.

[0059] **FIG. 4B** shows a V2X system 450 for communication between a vehicle 452 and a vehicle 454 through a network entity 456. These network communications may occur through discrete nodes, such as a BS (e.g., the BS 110a), that sends and receives information to and from (for example, relays information between) vehicles 452, 454. The network communications through vehicle to network (V2N) links 458 and 410 may be used, for example, for long range communications between vehicles, such as for communicating the presence of a car accident a distance ahead along a road or highway. Other types of communications may be sent by the wireless node to vehicles, such as traffic flow conditions, road hazard warnings, environmental/weather reports, and service station availability, among other examples. Such data can be obtained from cloud-based sharing services.

[0060] Roadside units (RSUs) may be utilized. An RSU may be used for V2I communications. In some examples, an RSU may act as a forwarding node to extend coverage for a UE. In some examples, an RSU may be co-located with a BS or may be standalone. RSUs can have different classifications. For example, RSUs can be classified into UE-type RSUs and Micro NodeB-type RSUs. Micro NB-type RSUs have similar functionality as the Macro eNB/gNB. The Micro NB-type RSUs can utilize the Uu interface. UE-type RSUs can be used for meeting tight quality-of-service (QoS) requirements by minimizing collisions and improving reliability. UE-type RSUs may use centralized resource allocation mechanisms to allow for efficient resource utilization. Critical information (e.g., such as traffic conditions, weather conditions, congestion statistics, sensor data, etc.) can be broadcast to UEs in the coverage area. Relays can re-broadcasts critical information received from some UEs. UE-type RSUs may be a reliable synchronization source.

[0061] Certain aspects of the present disclosure generally relate to techniques for CSI forwarding. In particular, certain aspects of the present disclosure provide advantages for improved sidelink communication reduce interference on uplink and enable spatial multiplexing.

[0062] In one resource allocation mode (e.g., sidelink resource allocation Mode 1), a serving gNB allocates sidelink resources for sidelink transmission. As shown in **FIG. 5**,

the UE 502 may send a sidelink buffer status report (SL-BSR) at 508 to the serving gNB 506 (e.g., via Uu). The SL-BSR provides the serving gNB 506 with information about sidelink data volume of logical channel identifiers (LDICs) to each destination ID. The gNB 506 receives the SL-BSR and provides a SL grant, at 510, to the UE 502 allocated resources for sidelink transmission from the transmitting UE 502 to the receiving UE 504. At 512, the UE 502 sends a SL transmission (e.g., via PC5) to the UE 504 using the granted resources.

[0063] In another resource allocation mode (e.g., sidelink resource allocation Mode 2), the UEs may autonomously select sidelink resources (e.g., time and/or frequency resources). As shown in **FIG. 6**, at 606, a transmitting UE 602 autonomously selects and reserves resources for sidelink transmission. At 608, the transmitting UE 602 sends a SL transmission to the receiving UE 604 using the autonomously selected resources (e.g., via PC5).

[0064] Unlike in uplink (UL) resource scheduling (e.g., in Uu), in sidelink resource allocation, the gNB may have no knowledge of channel, CSI, modulation and coding scheme (MCS), and/or rank recommendations for the sidelink. Thus, the BS may not be able to perform spatial multiplexing of transmissions.

[0065] Therefore, what is needed are techniques and apparatus for resource allocation in SL, for example, to enable scheduling and execution of spatial multiplexing in SL.

Example CSI Forwarding in Sidelink

[0066] Aspects of the present disclosure provide techniques and apparatus for forwarding sidelink (SL) channel state information (CSI) and/or scheduling information to a base station (BS). In some examples, a sidelink device can forward CSI and/or scheduling information, received from another sidelink device, to the serving BS. In some examples, a sidelink device can determine CSI and provide the CSI directly to the BS. The BS may use the CSI and/or scheduling information for resource allocation. For example, the BS may use the CSI and/or scheduling information for sidelink spatial multiplexing. The BS may use the CSI and/or scheduling information to mitigate interference, for example, in uplink and SL coexistence.

[0067] **FIG. 7** is a flow diagram illustrating example operations 700 for wireless communication, in accordance with certain aspects of the present disclosure. The operations 700 may be performed, for example, by a SL device (e.g., the UE 120a and/or

the UE 120b in the wireless communication network 100). The operations 700 may be implemented as software components that are executed and run on one or more processors (e.g., controller/processor 280 of **FIG. 2**). Further, the transmission and reception of signals by the apparatus in operations 700 may be enabled, for example, by one or more antennas (e.g., antennas 252 of **FIG. 2**). In certain aspects, the transmission and/or reception of signals by the apparatus may be implemented via a bus interface of one or more processors (e.g., controller/processor 280) obtaining and/or outputting signals.

[0068] The operations 700 may begin, at 702, by determining CSI for a SL channel between the SL device and another SL device. At 704, the first SL device transmits the CSI to a BS.

[0069] As shown in **FIG. 8**, the serving gNB 110a may receive a SL-BSR at 802 from the UE 120a. In response to the SL-BSR, the gNB 110a may provide a SL grant at 804 to the UE 120a, allocating resources for transmission to the UE 120c. In some examples, the SL-BSR and the SL grant may be sent via a cellular interface (e.g., Uu). The receiving UE 120c may be in a different cell (e.g., inter-cell) than the UE 120a and served the gNB 110b.

[0070] The UE 120c may receive a SL transmission at 808 from the UE 120a. The SL transmission at 808 from the UE 120a may include sidelink control information (SCI) (e.g., in physical sidelink control channel (PSCCH) with the resource allocation information of the grant from the gNB 110a for SL transmission from the UE 120a to the UE 120c. The SL transmission at 808 may also include data (e.g., in a physical sidelink shared channel (PSSCH)). The UE 120c may determine sidelink CSI at 809 based on measurements of the sidelink channel. The UE 120c I to send a CSI report at 810 to the UE 120a. CSI may include channel quality indicator (CQI) feedback, precoder matrix indicator (PMI) feedback, rank indicator (RI) feedback, and/or other feedback. In some examples, the UE 120c sends the CSI report via unicast in a SL medium access control (MAC) control element (CE). In some examples, the UE 120c sends the CSI report via groupcast.

[0071] The UE 120a, may then forward the sidelink CSI to the gNB 110a at 812. For example, the gNB 110a may forward the sidelink CSI in uplink control information (UCI) on the physical uplink control channel (PUCCH) or physical uplink shared channel (PUSCH), or in a MAC-CE to the gNB 110a. In certain aspects, the UE 120a can send

scheduling information, such as a preferred rank, MCS, and/or any other suitable scheduling information along with the CSI to the gNB 110a at 812.

[0072] In some examples, the UE may send the CSI and/or scheduling information to the BS with the BSR. As shown in **FIG. 9**, the UE 120a may include the destination index (e.g., the destination ID), a logical channel (or logical channel group) ID, the buffer size, along with additional bits (e.g., 2 bits) to indicate the RI (e.g., for up to 4 layers), and addition bits (e.g., 4 bits) to indicate the CQI (e.g., wideband CQI for the destination ID). Additionally, as shown in **FIG. 9**, the message may include additional reserved bits to indicate other scheduling information (e.g., MCS) to the gNB 110a. In certain aspects, forwarding such scheduling information to the gNB 110a may enable possible spatial transmission scheduling by the gNB 110a.

[0073] In some cases, the transmitting UE (e.g., UE 120a) may receive, and forward to the BS, CSI reports from multiple UEs of a certain destination ID. The CSI reports may be sent as part of SL feedback information (e.g., via UCI or MAC-CE).

[0074] According to certain aspects, as shown **FIG. 10**, the UE 120b may be served by the same serving cell (e.g., gNB 110a) as the UE 120a (e.g., intra-cell). In this case, both the UE 120a and 120b are RRC connected with the gNB 110a. Similar to the call flow depicted in **FIG. 8**, the UE 120a may send a SL-BSR at 1008 to the gNB 110a, and receive a SL grant at 1010 from the gNB 110a. As shown, both of the SL BSR and the SL grant may be sent over Uu. The UE 120a may send a SL transmission at 1012 to the UE 120c. The SL transmission at 1012 may include cell ID (e.g., the serving gNB 110a) information (e.g., in addition to the SCI and data).

[0075] The UE 120b may determine (e.g., measure and/or compute) CSI at 1014 for the sidelink channel with the UE 120a. Because the UE 120b has a connection with the gNB 110a, the UE 120b may forward a sidelink CSI report directly to the gNB 110a at 1018. For example, based on the cell ID in the SL transmission from UE 120a, the UE 120b can detect at 1016 that the UE 120a and UE 120b are served by the cell, and the UE 120b can send the sidelink CSI report to the gNB 110a at 1018 based on the detection. In certain aspects, the UE 120b may also include a source ID (e.g., of the UE 120b) and a destination ID (e.g., of the UE 120a) with the CSI report. The UE 120b may send the sidelink CSI report in UCI or MAC-CE.

[0076] In certain aspects, forwarding CSI from the UE 120c may reduce the burden on the UE 120a to forward CSI to the gNB 110a, but may be best applied with specific UCI resource pre-allocation for the UE 120b.

[0077] In certain aspects, in addition to forwarding the CSI report to the gNB 110a, the UE 120b may also forward hybrid automatic repeat request (HARQ) information to the gNB 110a.

[0078] As shown in **FIG. 10**, the UE 120a may also indicate MCS (selected/used for the sidelink transmission to the UE 120b) and/or other scheduling information to the gNB 110a via UCI or MAC-CE at 1020.

[0079] Based on the forwarded CSI report and/or scheduling information (e.g., MCS) the gNB can allocate resources for sidelink transmission. For example, the gNB 110a may schedule time and frequency resources, as well as rank and other scheduling information (e.g., MCS), for the UE 120a to send a sidelink transmission to the UE 120b. The gNB 110a may use the CSI report and scheduling information to schedule spatial multiplexing to mitigate interference for SL and UL coexistence.

[0080] In certain aspects, in other transmission modes, such as groupcast, the UE 120a may determine the RI and/or CSI of a specific SL transmission. The rank, MCS, and other scheduling information may be determined based on a pass-loss measurement, CSI report received from other UEs (e.g., the UE 120c), HARQ feedback from other UEs, and/or packet priority from higher layer quality of service (QoS) management. After making such determination, the UE 120a may send the RI, CSI, and/or MCS decisions to the gNB 110a while making the resource allocation request. In some cases, the information may be sent with the SL BSR via MAC CE. According to certain aspects, the CSI and/or other scheduling information may be sent via UCI as part of SL feedback information to the gNB 110a. According to certain aspects, the CSI and/or other scheduling information may be sent only when the RI changes.

[0081] According to certain aspects, the gNBs may receive forwarded CSI to enable spatial multiplexing. **FIG. 11** is a flow diagram illustrating example operations 1100 for wireless communication, in accordance with certain aspects of the present disclosure. The operations 1100 may be performed, for example, by a BS (e.g., the BS 110a in the wireless communication network 100). The operations 1100 may be implemented as software components that are executed and run on one or more processors (e.g.,

controller/processor 280 of **FIG. 2**). Further, the transmission and reception of signals by the apparatus in operations 1100 may be enabled, for example, by one or more antennas (e.g., antennas 252 of **FIG. 2**). In certain aspects, the transmission and/or reception of signals by the wireless node may be implemented via a bus interface of one or more processors (e.g., controller/processor 280) obtaining and/or outputting signals.

[0082] The operations 1100 may begin, at 1102, by receiving CSI for a SL channel between a SL device and another SL device. At 1104, the BS sends a resource allocation to at least one of the SL device or the another SL device based on the CSI.

[0083] **FIG. 12** illustrates a communications device 1200 that may include various components (e.g., corresponding to means-plus-function components) configured to perform operations for the techniques disclosed herein, such as the operations illustrated in **FIG. 7**. The communications device 1200 includes a processing system 1202 coupled to a transceiver 1208 (e.g., a transmitter and/or a receiver). The transceiver 1208 is configured to transmit and receive signals for the communications device 1200 via an antenna 1210, such as the various signals as described herein. The processing system 1202 may be configured to perform processing functions for the communications device 1200, including processing signals received and/or to be transmitted by the communications device 1200.

[0084] The processing system 1202 includes a processor 1204 coupled to a computer-readable medium/memory 1212 via a bus 1206. In certain aspects, the computer-readable medium/memory 1212 is configured to store instructions (e.g., computer-executable code) that when executed by the processor 1204, cause the processor 1204 to perform the operations illustrated in **FIG. 7**, or other operations for performing the various techniques discussed herein for receiver side protection in SL communication. In certain aspects, computer-readable medium/memory 1212 stores code 1214 for determining CSI for a SL channel between the SL device and another SL device; and code 1216 for transmitting the CSI to a base station (BS). In certain aspects, the processor 1204 has circuitry configured to implement the code stored in the computer-readable medium/memory 1212. The processor 1204 includes circuitry 1218 for determining channel state information (CSI) for a SL channel between the SL device and another SL device; and circuitry 1220 for transmitting the CSI to a base station (BS).

[0085] **FIG. 13** illustrates a communications device 1300 that may include various components (e.g., corresponding to means-plus-function components) configured to perform operations for the techniques disclosed herein, such as the operations illustrated in **FIG. 11**. The communications device 1300 includes a processing system 1302 coupled to a transceiver 1308 (e.g., a transmitter and/or a receiver). The transceiver 1308 is configured to transmit and receive signals for the communications device 1300 via an antenna 1310, such as the various signals as described herein. The processing system 1302 may be configured to perform processing functions for the communications device 1300, including processing signals received and/or to be transmitted by the communications device 1300.

[0086] The processing system 1302 includes a processor 1304 coupled to a computer-readable medium/memory 1312 via a bus 1306. In certain aspects, the computer-readable medium/memory 1312 is configured to store instructions (e.g., computer-executable code) that when executed by the processor 1304, cause the processor 1304 to perform the operations illustrated in **FIG. 11** or other operations for performing the various techniques discussed herein for receiver side protection in SL communication. In certain aspects, computer-readable medium/memory 1312 stores code 1314 for receiving channel state information (CSI) for a SL channel between a SL device and another SL device; and code 1316 for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI. In certain aspects, the processor 1304 has circuitry configured to implement the code stored in the computer-readable medium/memory 1312. The processor 1304 includes circuitry 1318 for receiving channel state information (CSI) for a SL channel between a SL device and another SL device; and circuitry 1320 for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI. In certain aspects, the processor 1304 has circuitry configured to implement the code stored in the computer-readable medium/memory 1312.

[0087] The techniques described herein may be used for various wireless communication technologies, such as NR (e.g., 5G NR), 3GPP Long Term Evolution (LTE), LTE-Advanced (LTE-A), code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal frequency division multiple access (OFDMA), single-carrier frequency division multiple access (SC-FDMA), time division synchronous code division multiple access (TD-SCDMA), and other networks. The terms "network" and "system" are often used

interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as NR (e.g. 5G RA), Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDMA, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). LTE and LTE-A are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). cdma2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). NR is an emerging wireless communications technology under development.

[0088] In 3GPP, the term "cell" can refer to a coverage area of a Node B (NB) and/or a NB subsystem serving this coverage area, depending on the context in which the term is used. In NR systems, the term "cell" and BS, next generation NodeB (gNB or gNodeB), access point (AP), distributed unit (DU), carrier, or transmission reception point (TRP) may be used interchangeably. A BS may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cells. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having an association with the femto cell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.). A BS for a macro cell may be referred to as a macro BS. A BS for a pico cell may be referred to as a pico BS. A BS for a femto cell may be referred to as a femto BS or a home BS.

[0089] A UE may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, a Customer Premises Equipment (CPE), a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a tablet computer, a camera, a gaming device, a netbook, a smartbook, an ultrabook, an appliance, a medical device or medical equipment, a

biometric sensor/device, a wearable device such as a smart watch, smart clothing, smart glasses, a smart wrist band, smart jewelry (e.g., a smart ring, a smart bracelet, etc.), an entertainment device (e.g., a music device, a video device, a satellite radio, etc.), a vehicular component or sensor, a smart meter/sensor, industrial manufacturing equipment, a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. Some UEs may be considered machine-type communication (MTC) devices or evolved MTC (eMTC) devices. MTC and eMTC UEs include, for example, robots, drones, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a BS, another device (e.g., remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices, which may be narrowband IoT (NB-IoT) devices.

[0090] In some examples, access to the air interface may be scheduled. A scheduling entity (e.g., a BS) allocates resources for communication among some or all devices and equipment within its service area or cell. The scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more subordinate entities. That is, for scheduled communication, subordinate entities utilize resources allocated by the scheduling entity. Base stations are not the only entities that may function as a scheduling entity. In some examples, a UE may function as a scheduling entity and may schedule resources for one or more subordinate entities (e.g., one or more other UEs), and the other UEs may utilize the resources scheduled by the UE for wireless communication. In some examples, a UE may function as a scheduling entity in a peer-to-peer (P2P) network, and/or in a mesh network. In a mesh network example, UEs may communicate directly with one another in addition to communicating with a scheduling entity.

[0091] The methods disclosed herein comprise one or more steps or actions for achieving the methods. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0092] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-c-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0093] As used herein, the term "determining" encompasses a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" may include resolving, selecting, choosing, establishing and the like.

[0094] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language of the claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112(f) unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."

[0095] For example, means for transmitting (or means for outputting for transmission) may include a transmitter and/or an antenna(s) 234 of the BS 110 or the transmitter unit 254 and/or antenna(s) 252 of the UE 120 illustrated in **FIG. 2**. Means for receiving (or means for obtaining) may include a receiver and/or an antenna(s) 234 of the BS 110 or a receiver and/or antenna(s) 252 of the UE 120 illustrated in **FIG. 2**. Means

for communicating may include a transmitter, a receiver or both. Means for generating, means for performing, means for determining, means for taking action, means for determining, means for coordinating may include a processing system, which may include one or more processors, such as the transmit processor 220, the TX MIMO processor 230, the receive processor 238, and/or the controller/processor 240 of the BS 110 or the receive processor 258, the transmit processor 264, the TX MIMO processor 266, and/or the controller/processor 280 of the UE 120 illustrated in **FIG. 2**.

[0096] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering.

[0097] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0098] If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the

PHY layer. In the case of a user terminal (see **FIG. 1**), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

[0099] If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0100] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0101] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer- readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0102] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein, for example, instructions for performing the operations described herein and illustrated in **FIG. 7** and/or **FIG. 11**.

[0103] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0104] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

CLAIMS

1. A method for wireless communication by a sidelink (SL) device, comprising:

determining channel state information (CSI) for a SL channel between the SL device and another SL device; and

transmitting the CSI to a base station (BS).

2. The method of claim 1, wherein the CSI comprises channel quality indicator (CQI), precoding matrix indicator (PMI), or a combination thereof.

3. The method of any of claims 1 or 2, wherein transmitting the CSI to the BS comprises transmitting the CSI in uplink control information (UCI) on a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH).

4. The method of any of claims 1-3, wherein transmitting the CSI to the BS comprises transmitting the CSI to the BS in a SL MAC-CE with one or more additional field indicating the CSI.

5. The method of any of claims 1-4, further comprising receiving a resource allocation from the BS based on the CSI.

6. The method of any of claims 1-5, wherein determining the CSI for the SL channel comprises:

receiving at least one CSI report from at least the another SL device.

7. The method of claim 6, further comprising send a sidelink transmission to the another SL device comprising SL control information (SCI) and data, wherein the CSI report from the another SL device is in response to the sidelink transmission.

8. The method of any of claims 6 or 7, wherein the another SL device is in a different cell than the SL device.

9. The method of any of claims 6-8, further comprising transmitting an indication of a modulation and coding scheme (MCS), rank indicator (RI), or both, used for the SL channel to the BS.

10. The method of any of claims 6-9, wherein the transmitting the CSI to the BS comprises transmitting the CSI to the BS in a buffer status report (BSR).

11. The method of any of claims 6-10, wherein receiving the at least one CSI report from at least the another SL device comprises receiving a plurality of CSI reports groupcast from a plurality of SL devices.

12. The method of claim 11, wherein the plurality of CSI reports include a destination identifier (ID) of the SL device.

13. The method of any of claims 1-12, wherein determining the CSI for the SL channel comprises:

receiving a sidelink transmission from the another SL device comprising SL control information (SCI) and data; and

determining the CSI based on measurements of the sidelink transmission.

14. The method of claim 13, wherein:

the SCI includes a cell ID indicating a serving cell of the another SL device; and transmitting the CSI to the BS comprises transmitting the CSI to the BS based on identifying that the serving cell of the another SL device is the same as a serving cell of the SL device.

15. The method of any of claims 13 or 14, wherein the transmitting the CSI to the BS comprises transmitting the CSI to the BS with a destination identifier (ID) of the another SL device.

16. The method of any of claims 13-15, further comprising transmitting hybrid automatic repeat request (HARQ) to the BS with the CSI.

17. The method of any of claims 1-16, wherein the CSI is transmitted only when a rank indicator (RI) changes.

18. A method for wireless communication by a base station (BS), comprising:

receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device; and

sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.

19. The method of claim 18, wherein sending the resource allocation to at least one of the SL device or the another SL device comprises spatially multiplexing sidelink transmission between the SL devices, uplink transmissions from one or more devices, or a combination thereof.

20. The method of any of claims 18 or 19, wherein the CSI comprises channel quality indicator (CQI), precoding matrix indicator (PMI), or a combination thereof.

21. The method of any of claims 18-20, wherein receiving the CSI comprises receiving the CSI in uplink control information (UCI) on a physical uplink control channel (PUCCH) or a physical uplink shared channel (PUSCH).

22. The method of any of claims 18-21, wherein receiving the CSI to the BS comprises receiving the CSI to the BS in a SL MAC-CE with one or more additional field indicating the CSI.

23. The method of any of claims 18-22, wherein the another SL device is in a different cell than the SL device.

24. The method of any of claims 18-23, further comprising receiving an indication of a modulation and coding scheme (MCS), rank indicator (RI), or both, used for the SL channel.

25. The method of any of claims 18-24, wherein the receiving the CSI comprises receiving the CSI in a buffer status report (BSR).

26. The method of any of claims 18-25, wherein the CSI includes a destination identifier (ID) of the another SL device.

27. The method of any of claims 18-26, further comprising receiving hybrid automatic repeat request (HARQ) with the CSI.

28. The method of any of claims 18-27, wherein the CSI is received only when a rank indicator (RI) changes.

29. An apparatus for wireless communication, comprising:

at least one processor; and

a memory coupled to the at least one processor, the memory comprising code executable by the at least one processor to cause the apparatus to:

determine channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device; and

transmit the CSI to a base station (BS).

30. An apparatus for wireless communication, comprising:

at least one processor; and

a memory coupled to the at least one processor, the memory comprising code executable by the at least one processor to cause the apparatus to:

to:

receive channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device; and

send a resource allocation to at least one of the SL device or the another SL device based on the CSI.

31. An apparatus for wireless communication, comprising:

means for determining channel state information (CSI) for a sidelink (SL) channel between the apparatus and a SL device; and

means for transmitting the CSI to a base station (BS).

32. An apparatus for wireless communication, comprising:

means for receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device; and

means for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.

33. A computer readable medium having instructions stored thereon that when executed cause a processor to:

determine channel state information (CSI) for a SL channel between a SL device and another SL device; and

transmit the CSI to a base station (BS).

34. A computer readable medium having instructions stored thereon that when executed cause a processor to:

receive channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device; and

send a resource allocation to at least one of the SL device or the another SL device based on the CSI.

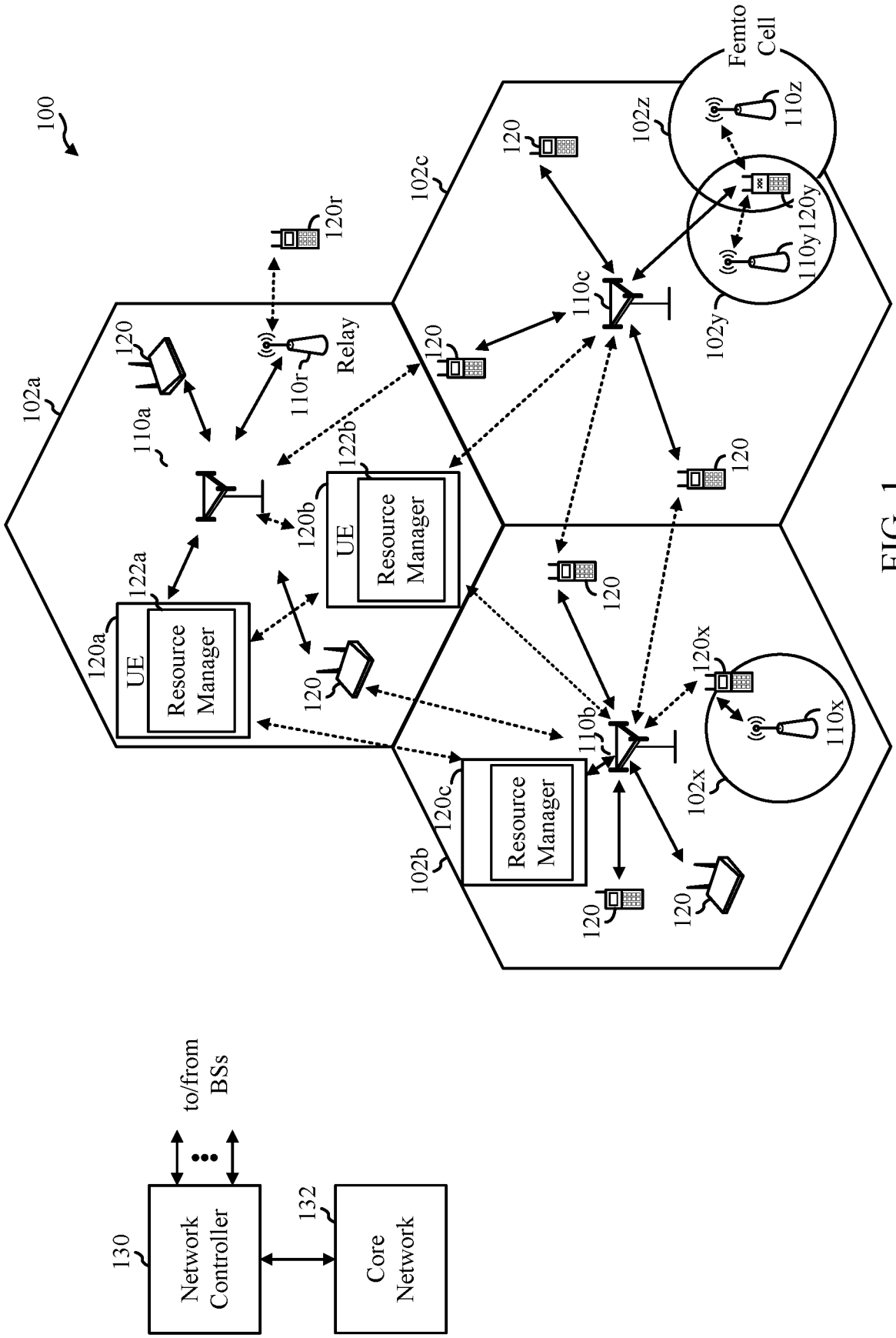

100
102a
102b
102c
102x
102y
102z
110a
110b
110c
110r
110x
110y
110z
120
120a
120b
120c
120r
120x
120y
122a
122b
Relay
Femto Cell
UE
Resource Manager
to/from BSs
130
Network Controller
132
Core Network

FIG. 1

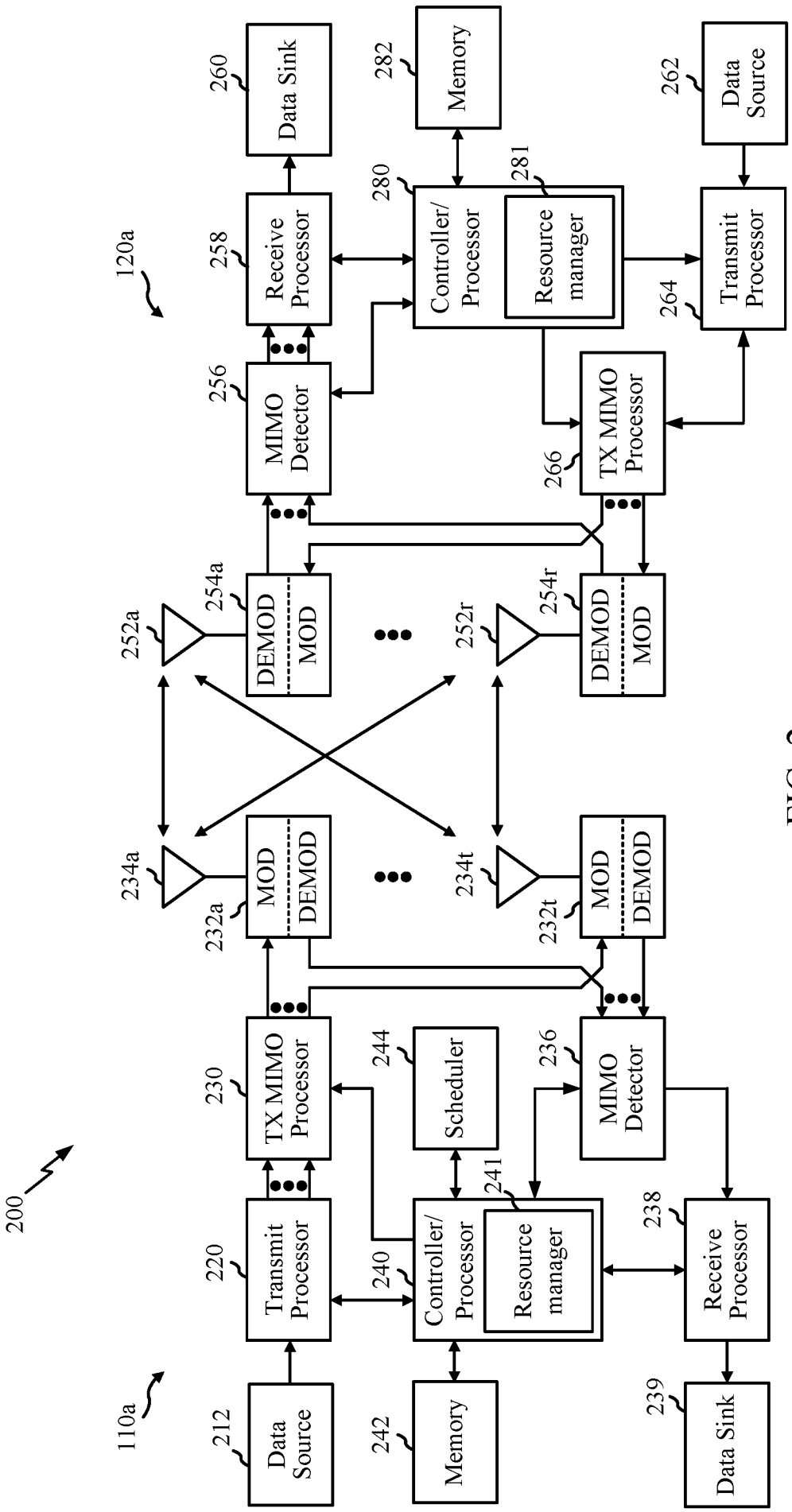

200
110a
120a
212
Data Source
220
Transmit Processor
230
TX MIMO Processor
232a
MOD
DEMOD
234a
252a
254a
DEMOD
MOD
256
MIMO Detector
258
Receive Processor
260
Data Sink
240
Controller/ Processor
241
Resource manager
242
Memory
244
Scheduler
234t
252r
254r
232t
236
MIMO Detector
238
Receive Processor
239
Data Sink
280
Controller/ Processor
281
Resource manager
282
Memory
262
Data Source
264
Transmit Processor
266
TX MIMO Processor

FIG. 2

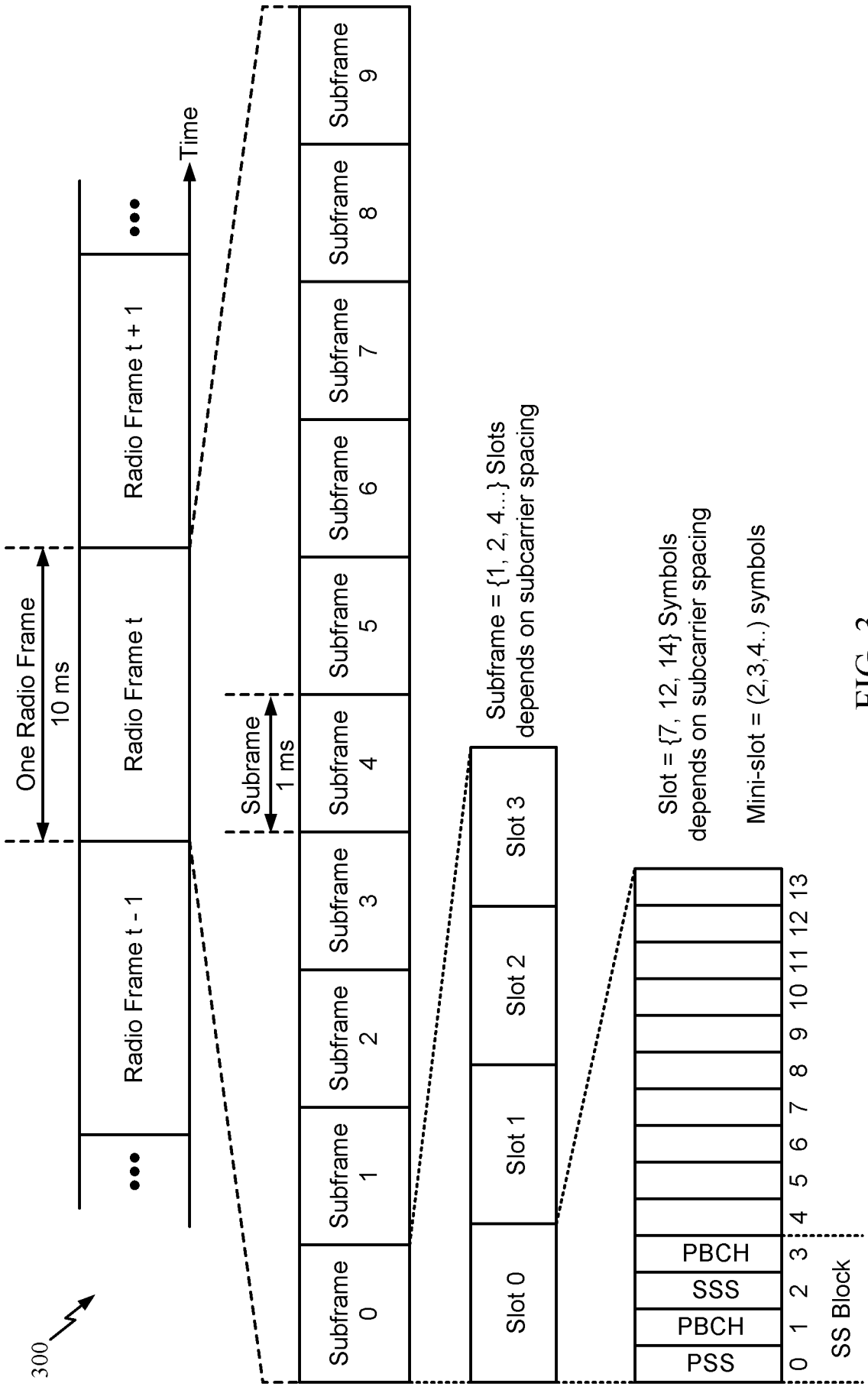

300
Time
One Radio Frame
10 ms
Radio Frame t - 1
Radio Frame t
Radio Frame t + 1
Subframe
1 ms
Subframe 0
Subframe 1
Subframe 2
Subframe 3
Subframe 4
Subframe 5
Subframe 6
Subframe 7
Subframe 8
Subframe 9
Slot 0
Slot 1
Slot 2
Slot 3
Subframe = {1, 2, 4...} Slots
depends on subcarrier spacing
Slot = {7, 12, 14} Symbols
depends on subcarrier spacing
Mini-slot = (2,3,4..) symbols
PSS
PBCH
SSS
PBCH
SS Block
0 1 2 3 4 5 6 7 8 9 10 11 12 13

FIG. 3

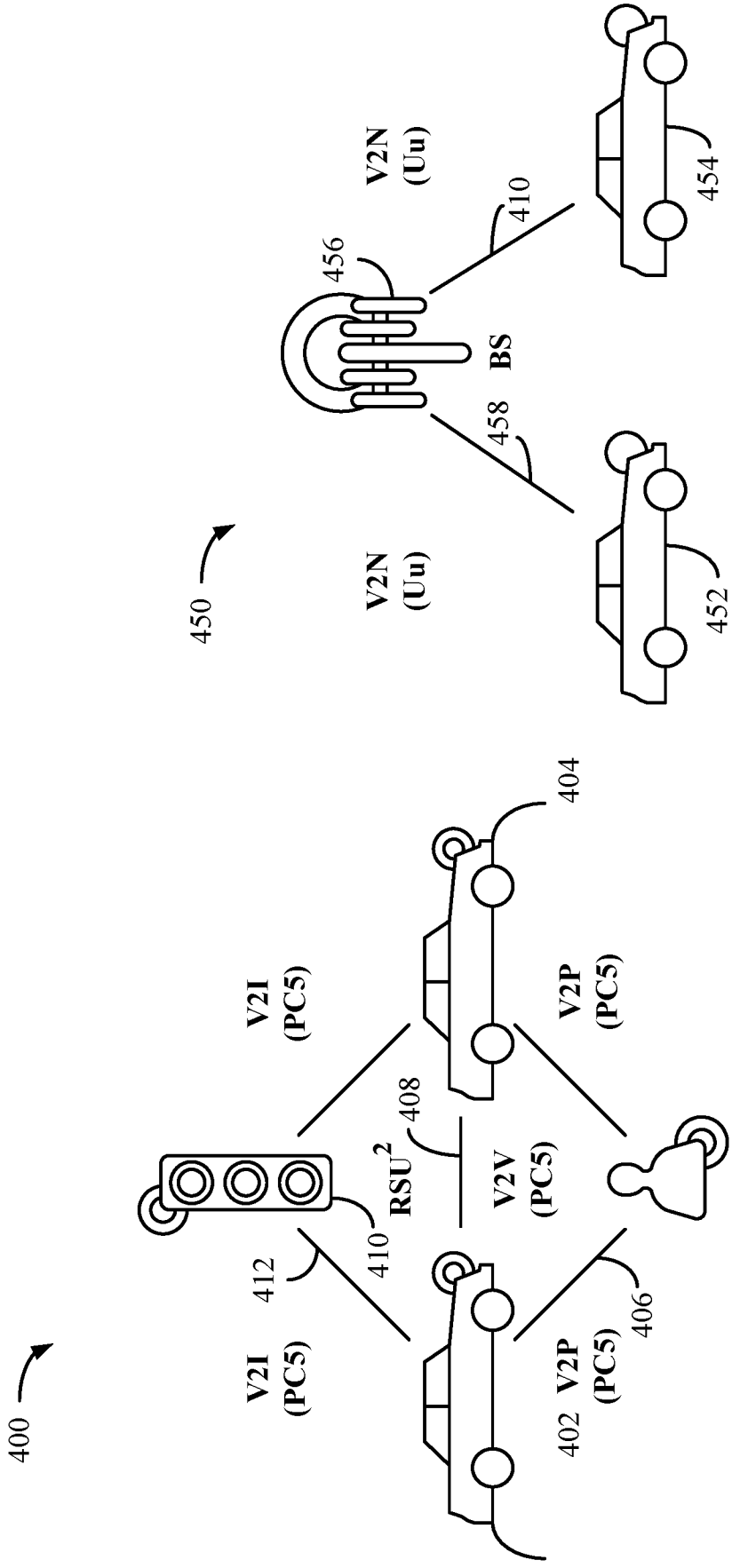

400
V2I (PC5)
V2I (PC5)
412
410
RSU
2
408
V2V (PC5)
V2P (PC5)
402
V2P (PC5)
406
404

FIG. 4A

450
V2N (Uu)
V2N (Uu)
458
456
BS
410
452
454

FIG. 4B

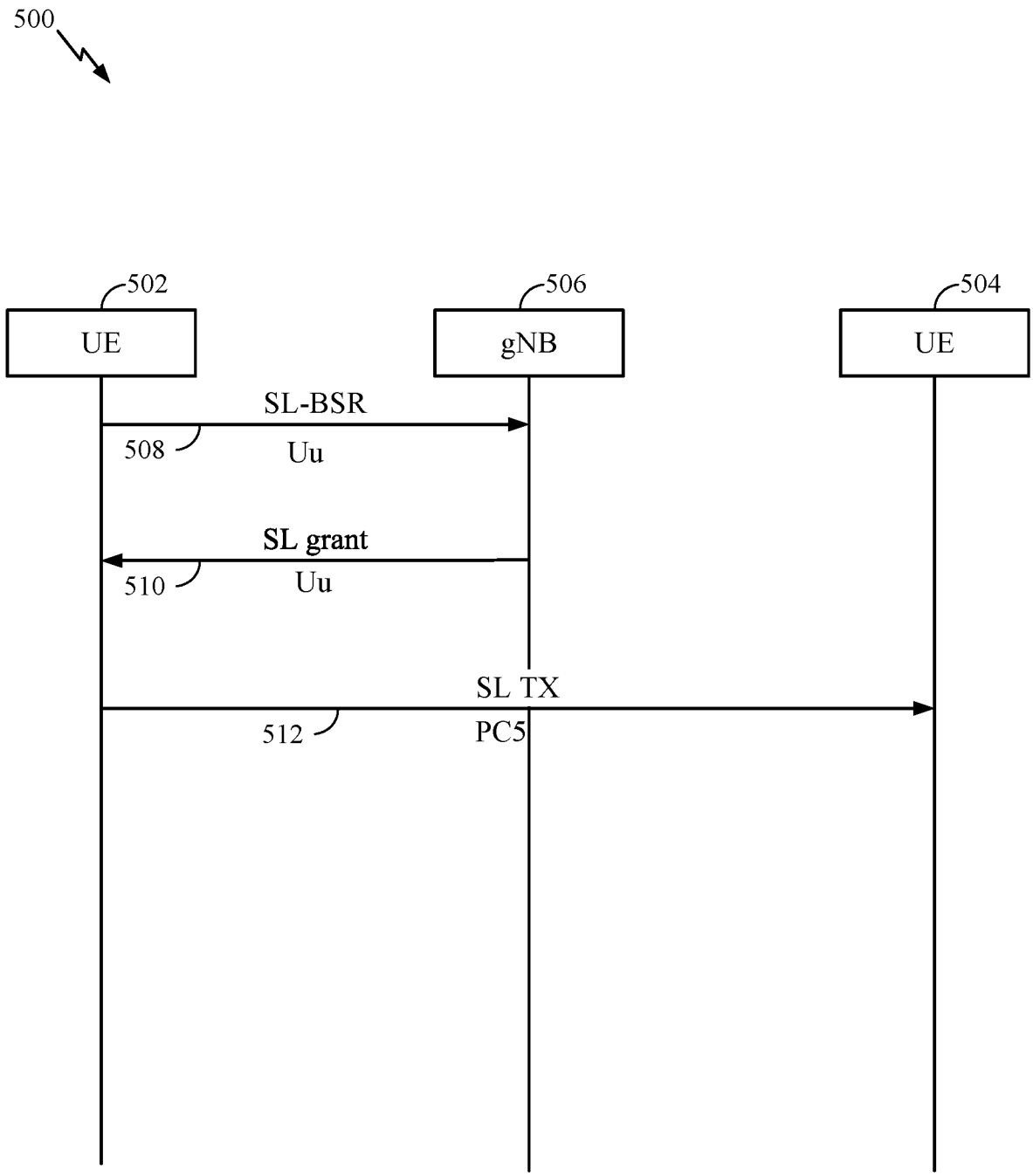

500
502
UE
506
gNB
504
UE
SL-BSR
508
Uu
SL grant
510
Uu
SL TX
512
PC5

FIG. 5

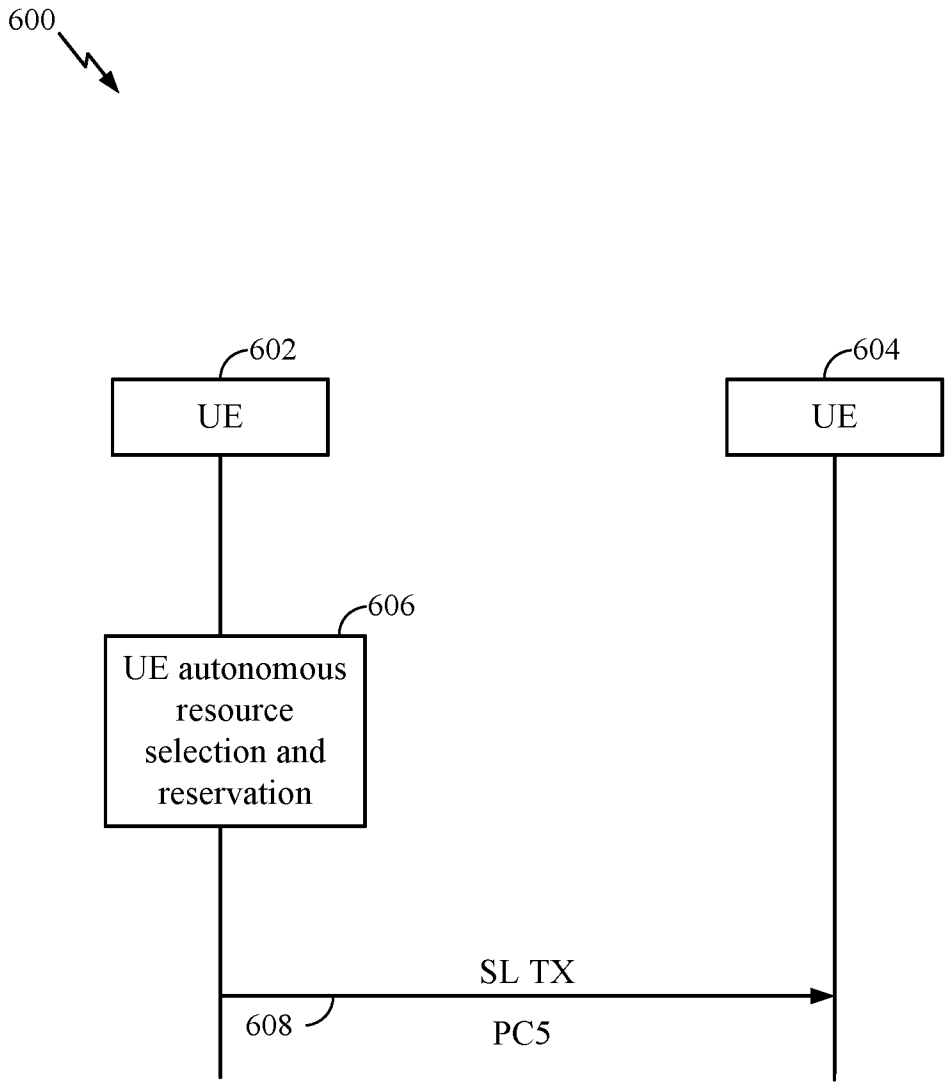

600
602
UE
604
UE
606
UE autonomous resource selection and reservation
SL TX
608
PC5

FIG. 6

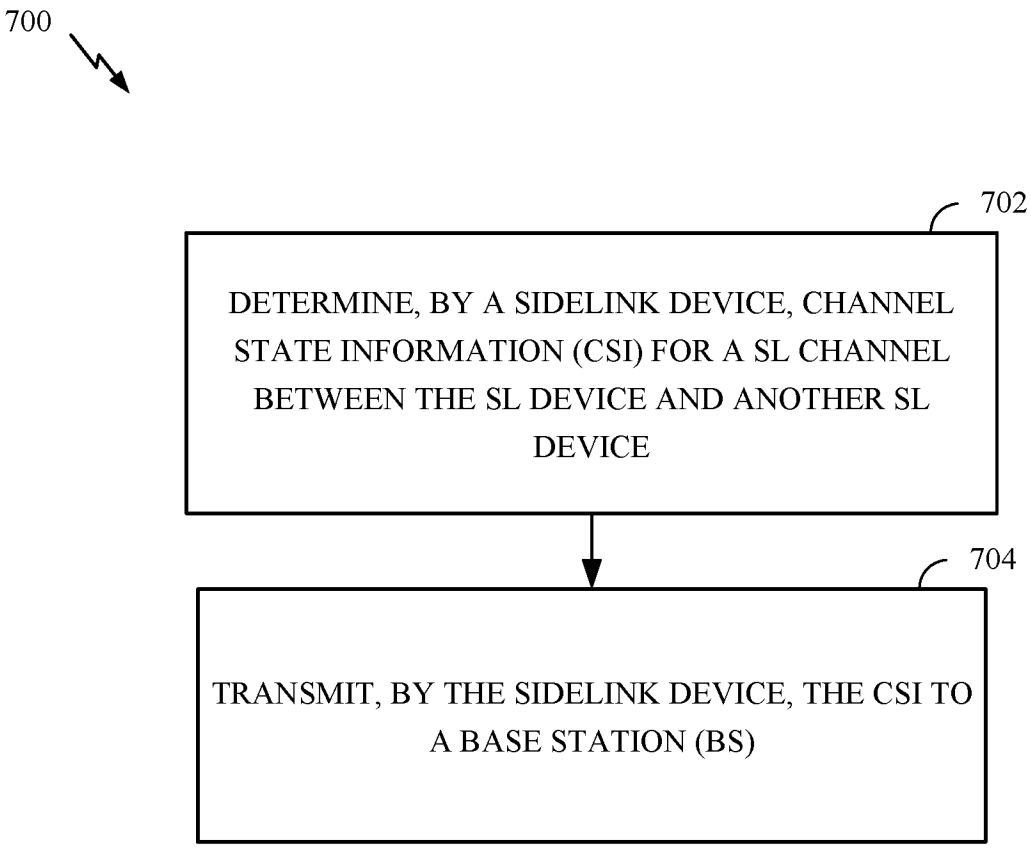

700
702
DETERMINE, BY A SIDELINK DEVICE, CHANNEL STATE INFORMATION (CSI) FOR A SL CHANNEL BETWEEN THE SL DEVICE AND ANOTHER SL DEVICE
704
TRANSMIT, BY THE SIDELINK DEVICE, THE CSI TO A BASE STATION (BS)

FIG. 7

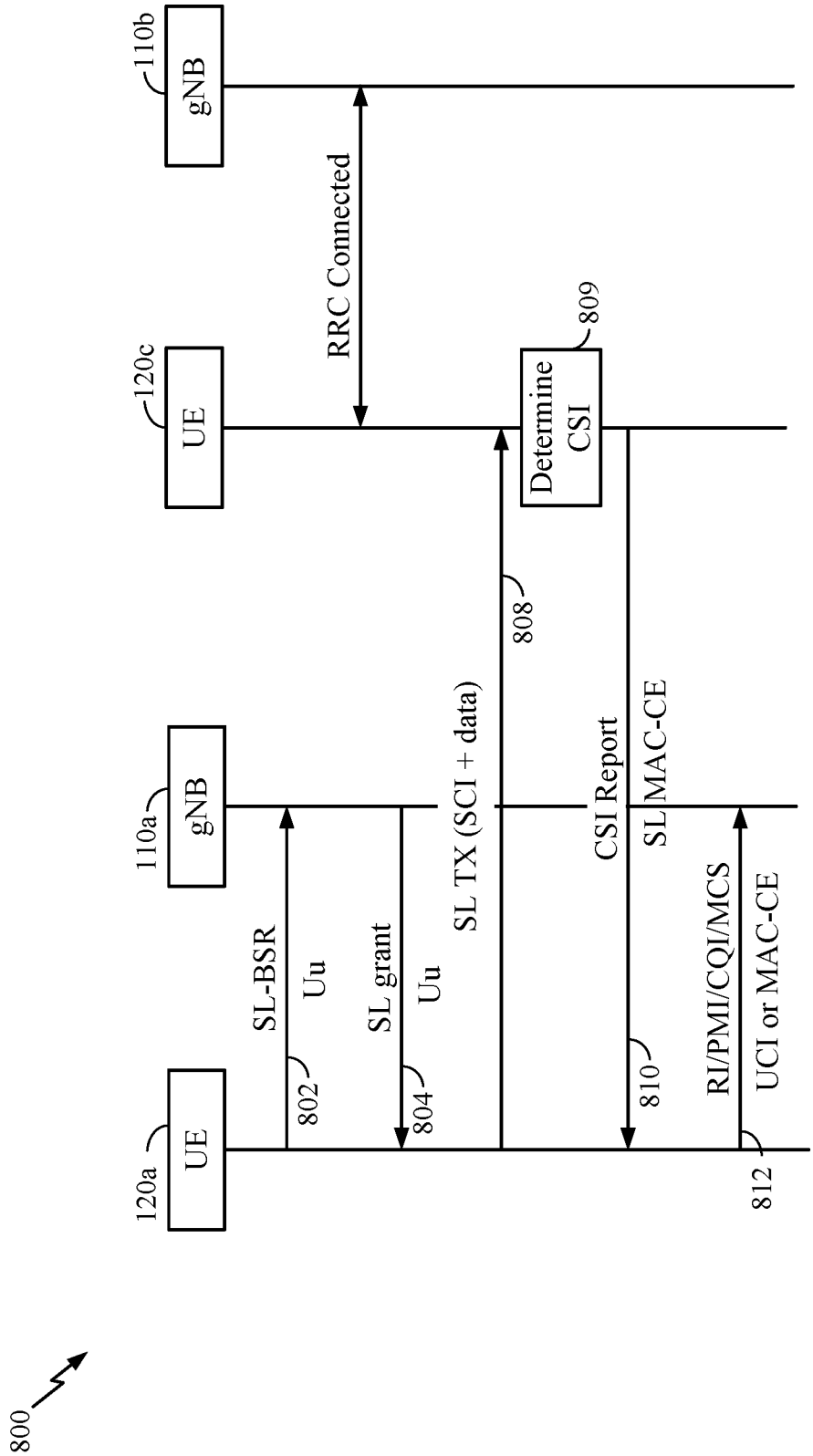
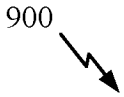

800
120a
UE
110a
gNB
120c
UE
110b
gNB
RRC Connected
Determine CSI
809
SL-BSR
Uu
802
SL grant
Uu
804
SL TX (SCI + data)
808
CSI Report
SL MAC-CE
810
RI/PMI/CQI/MCS
UCI or MAC-CE
812

FIG. 8



DESTINATION INDEX$_1$		LCG ID$_1$	
BUFFER SIZE$_1$			
RI$_1$	CQI$_1$	R	R

FIG. 9

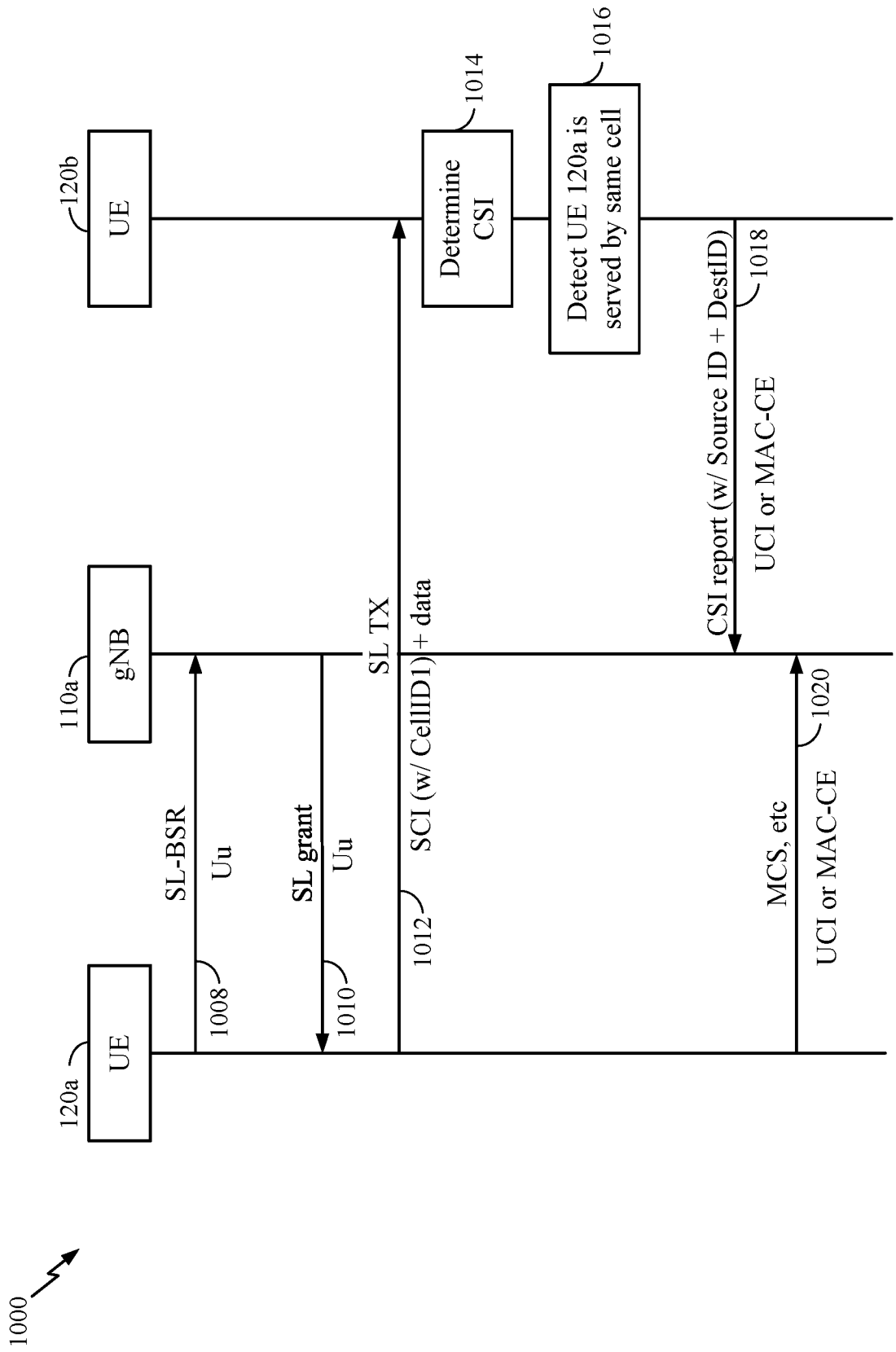

1000
120a
UE
110a
gNB
120b
UE
SL-BSR
Uu
1008
SL grant
Uu
1010
SL TX
SCI (w/ CellID1) + data
1012
Determine CSI
1014
Detect UE 120a is served by same cell
1016
CSI report (w/ Source ID + DestID)
UCI or MAC-CE
1018
MCS, etc
UCI or MAC-CE
1020

FIG. 10

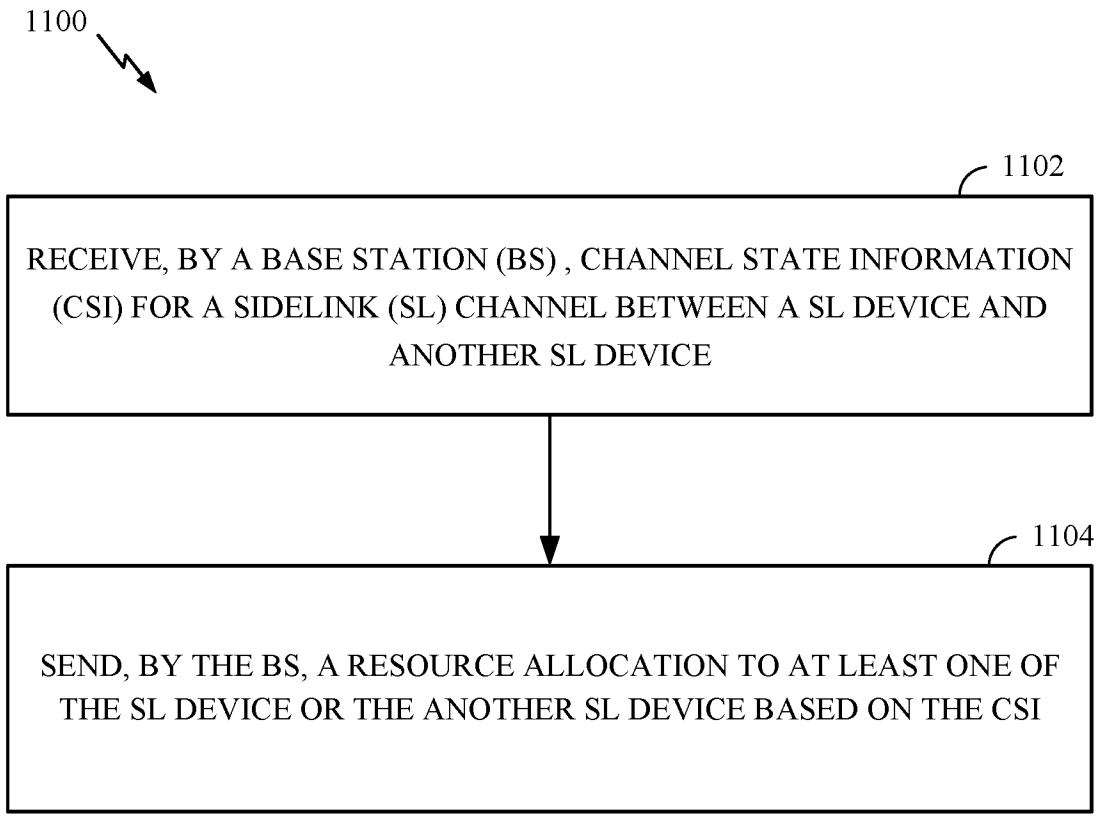

1100
1102
RECEIVE, BY A BASE STATION (BS) , CHANNEL STATE INFORMATION (CSI) FOR A SIDELINK (SL) CHANNEL BETWEEN A SL DEVICE AND ANOTHER SL DEVICE
1104
SEND, BY THE BS, A RESOURCE ALLOCATION TO AT LEAST ONE OF THE SL DEVICE OR THE ANOTHER SL DEVICE BASED ON THE CSI

FIG. 11

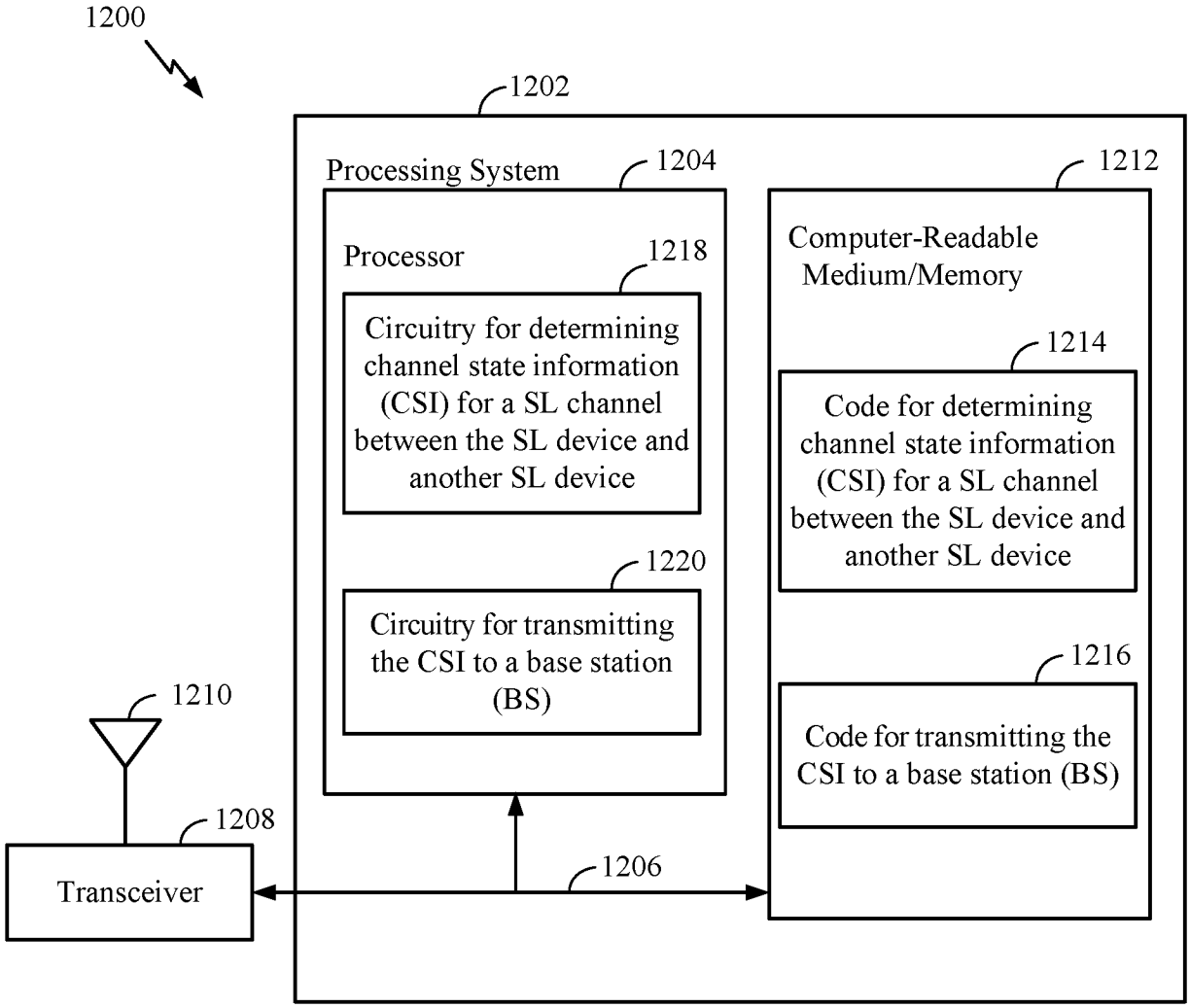

1200
1202
Processing System
1204
Processor
1218
Circuitry for determining channel state information (CSI) for a SL channel between the SL device and another SL device
1220
Circuitry for transmitting the CSI to a base station (BS)
1212
Computer-Readable Medium/Memory
1214
Code for determining channel state information (CSI) for a SL channel between the SL device and another SL device
1216
Code for transmitting the CSI to a base station (BS)
1210
1208
Transceiver
1206

FIG. 12

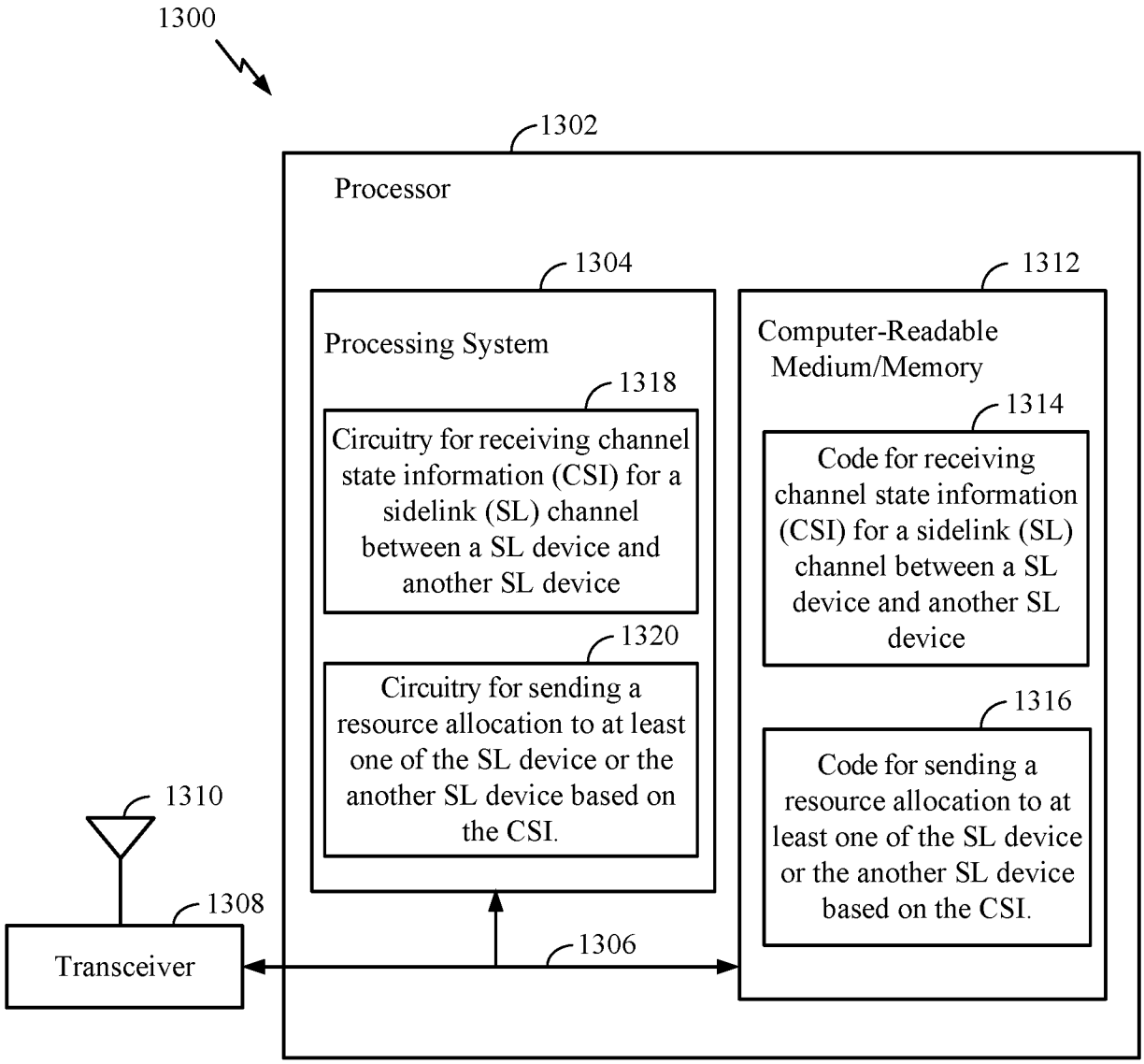

1300
1302
Processor
1304
Processing System
1318
Circuitry for receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device
1320
Circuitry for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.
1312
Computer-Readable Medium/Memory
1314
Code for receiving channel state information (CSI) for a sidelink (SL) channel between a SL device and another SL device
1316
Code for sending a resource allocation to at least one of the SL device or the another SL device based on the CSI.
1310
1308
Transceiver
1306

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2020/091782

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/00(2006.01)i; H04W 4/40(2018.01)i; H04W 24/10(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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)

CNPAT;CNKI;WPI;EPODOC;3GPP:CSI, sidelink, channel, gNB, BS, base, station, allocate, resource

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ERICSSON. "On PHY procedures to support unicast and groupcast on NR sidelink" *3GPP TSG-RAN WG1 Meeting #95 R1-1813639,* 16 November 2018 (2018-11-16), section 4	1-17, 29, 31, 33
Y	ERICSSON. "On PHY procedures to support unicast and groupcast on NR sidelink" *3GPP TSG-RAN WG1 Meeting #95 R1-1813639,* 16 November 2018 (2018-11-16), section 4	18-28, 30, 32, 34
Y	CN 110971370 A (SHARP CORPORATION) 07 April 2020 (2020-04-07) description, paragraph 0005	18-28, 30, 32, 34
A	WO 2018056730 A1 (SAMSUNG ELECTRONICS CO., LTD.) 29 March 2018 (2018-03-29) the whole document	1-34
A	WO 2018056728 A1 (SAMSUNG ELECTRONICS CO., LTD.) 29 March 2018 (2018-03-29) the whole document	1-34
A	CN 109644455 A (BEIJING XIAOMI MOBILE SOFTWARE CO., LTD.) 16 April 2019 (2019-04-16) the whole document	1-34

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 February 2021	**23 February 2021**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China** Facsimile No. **(86-10)62019451**	Authorized officer **XIAO,Yu** Telephone No. **86-(10)-53961588**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2020/091782

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	110971370	A	07 April 2020	WO	2020063747	A1	02 April 2020
WO	2018056730	A1	29 March 2018	KR	20190045920	A	03 May 2019
				CN	109906661	A	18 June 2019
				US	2018092129	A1	29 March 2018
				EP	3501227	A1	26 June 2019
				VN	64135	A	25 June 2019
				IN	201937011024	A	03 May 2019
WO	2018056728	A1	29 March 2018	EP	3513509	A1	24 July 2019
				CN	109845137	A	04 June 2019
				KR	20190045388	A	02 May 2019
				US	2018083680	A1	22 March 2018
				IN	201917015573	A	26 July 2019
CN	109644455	A	16 April 2019	WO	2020107346	A1	04 June 2020