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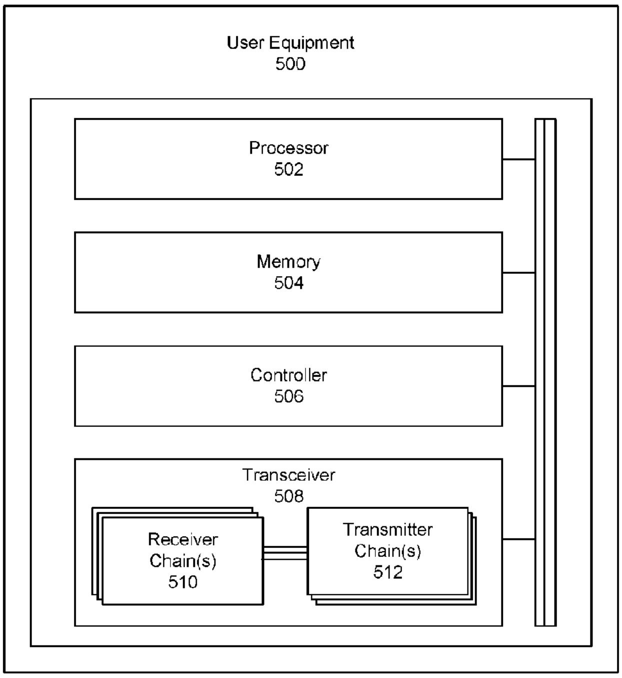

FIG. 5

(57) **Abstract:** Apparatuses, methods, and systems are disclosed for PSFCH priority determination. One UE (500) includes a processor (502) coupled with a memory (504) and configured to cause the UE (500) to generate (802) a first set of PSFCH transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set including a respective PSFCH transmission carrying HARQ-ACK information, and to increase (804) a priority of the respective PSFCH transmission based on one or more conditions being satisfied. The processor (502) is further configured to cause the UE (500) to transmit (806) a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, wherein the second set includes a portion of the first set.

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TECHNIQUES FOR PRIORITIZING SIDELINK FEEDBACK RESOURCES FOR HARQ-ACK ON AN UNLICENSED CARRIER

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to techniques for assessing (e.g., determining, identifying, evaluating, defining) priority of sidelink (SL) resources for SL communication on an unlicensed carrier, including a physical sidelink feedback channel (PSFCH) transmission carrying hybrid automatic repeat request acknowledgement (HARQ-ACK) information.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an evolved NodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station 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 resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) Radio Access Technology (RAT), fourth generation (4G) RAT, fifth generation (5G) RAT, among other suitable RATs beyond 5G (e.g., sixth generation (6G)). The wireless communications systems may also support SL communication between UEs.

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 method and apparatuses described herein may include a receiving UE (Rx UE) comprising a means for generating a first set of PSFCH transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set including a respective PSFCH transmission carrying HARQ-ACK information. The Rx UE may comprise means for increasing a priority of the respective PSFCH transmission based on a transmission time of a physical sidelink shared channel (PSSCH) transmission corresponding to the HARQ-ACK information, an indication in sidelink control information (SCI) associated with the respective PSFCH transmission, a cast type of the PSSCH transmission, or an acknowledgement type of the HARQ-ACK information, or a combination thereof. The UE may comprise means for transmitting a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, where the second set includes a portion of the first set.

[0005] Other implementations of the method and apparatuses described herein may include a transmitting UE (Tx UE) comprising a means for transmitting a plurality of PSSCH transmissions to a receiving device (e.g., a Rx UE). The Tx UE may comprise transmitting SCI associated with the plurality of PSSCH transmissions, where the SCI includes an indication that a respective PSSCH transmission is within a reference duration. The Tx UE may comprise means for receiving, from the receiving device and over an unlicensed carrier, a set of PSFCH transmissions comprising a respective PSFCH transmission carrying HARQ-ACK information corresponding to the respective PSSCH transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 illustrates an example of a wireless communication system in accordance with aspects of the present disclosure.

[0007] Figure 2 illustrates an example of a protocol stack showing different protocol layers in the UE and network, in accordance with aspects of the present disclosure.

[0008] Figure 3 illustrates an example of a SL protocol stack in accordance with aspects of the present disclosure.

[0009] Figure 4 illustrates an example of SCI in accordance with aspects of the present disclosure in accordance with aspects of the present disclosure.

[0010] Figure 5 illustrates an example of a UE in accordance with aspects of the present disclosure.

[0011] Figure 6 illustrates an example of a processor in accordance with aspects of the present disclosure.

[0012] Figure 7 illustrates an example of a network equipment (NE) in accordance with aspects of the present disclosure.

[0013] Figure 8 is a flowchart diagram illustrating one embodiment of a method for PSFCH priority determination.

[0014] Figure 9 is a flowchart diagram illustrating another embodiment of a method for PSFCH priority determination.

DETAILED DESCRIPTION

[0015] The present disclosure describes systems, methods, and apparatuses for assessing (e.g., determining, identifying, evaluating, defining) priority of SL resources for SL communication, including a PSFCH transmission on an unlicensed carrier. In certain embodiments, the methods may be performed using computer code embedded on a computer-readable medium. In certain embodiments, an apparatus or system may include a computer-readable medium containing computer-readable code which, when executed by a processor, causes the apparatus or system to perform at least a portion of the below described solutions.

[0016] In certain regulatory domains, access to an unlicensed carrier (i.e., shared spectrum) is only allowed following a successful clear channel assessment, e.g., by listen-before-talk, with a variable random back-off contention window (CW). The CW duration is generally determined as a uniformly distributed random value between a lower bound and upper bound; these bounds are maintained/updated (e.g., increased or decreased) as a function of whether a previous transmission succeeded or not, which is determined by evaluating the HARQ-ACK feedback transmitted by the transmission's recipient(s).

[0017] In Third Generation Partnership Project (3GPP) new radio (NR) sidelink, a UE may be capable of transmitting multiple HARQ-ACK at the same time. In case more HARQ-ACK transmissions are scheduled than the capability, a priority procedure is evaluated to determine which HARQ-ACK values are being transmitted and which are dropped.

[0018] This disclosure provides solutions to establish HARQ-ACK priorities corresponding to transmissions that are relevant for updating the CW boundaries. As used herein, "HARQ-ACK" may represent collectively the positive acknowledge (ACK) and the negative acknowledge (NACK). ACK means that a transport block (TB) is correctly received while NACK means a TB is erroneously received. In the present disclosure, HARQ-ACK information may also be referred to as "HARQ feedback."

[0019] Aspects of the present disclosure are described in the context of a wireless communications system. Aspects of the present disclosure are further illustrated and described with reference to system diagrams, device diagrams, configuration parameter diagrams, and flowcharts.

[0020] Figure 1 illustrates an example of a wireless communications system 100 in accordance with 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 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 (i.e., Wi-Fi), IEEE 802.16 (i.e., 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.

[0021] 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 eNB, a 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.

[0022] 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.

[0023] 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.

[0024] 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 SL. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0025] 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, 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).

[0026] 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 (CP) entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane (UP) 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 CP 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.

[0027] The CN 106 may communicate with a packet data network over one or more backhaul links (e.g., via an S1, N2, 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).

[0028] 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.

[0029] 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., μ=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., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=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., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0030] 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.

[0031] 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., μ=0, μ=1, μ=2, μ=3, μ=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., orthogonal frequency division multiplexing (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., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0032] 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 (410 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 – 300 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.

[0033] 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., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=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., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0034] For initial access, a UE 104 detects a candidate cell and performs downlink (DL) synchronization. For example, the gNB (e.g., an embodiment of the NE 102) may transmit a synchronization signal and broadcast channel (SS/PBCH) transmission, referred to as a synchronization signal block (SSB). The synchronization signal is a predefined data sequence known to the UE 104 (or derivable using information already stored at the UE 104) and is in a predefined location in time relative to frame/subframe boundaries, etc. The UE 104 searches for the SSB and uses the SSB to obtain DL timing information (e.g., symbol timing) for the DL synchronization. The UE 104 may also decode system information (SI) based on the SSB.

[0035] Note that with beam-based communication, each DL beam may be associated with a respective SSB. In 3GPP NR, the gNB may transmit the maximum 64 SSBs and the maximum 64 corresponding copies of physical downlink control channel (PDCCH) and/or physical downlink shared channel (PDSCH) for delivery of system information block #1 (SIB1) in high frequency bands (e.g., 28 GHz).

[0036] In the following, instead of “slot,” the terms “mini-slot,” “subslot,” or “aggregated slots” can also be used, wherein the notion of slot/mini-slot/sub-slot/aggregated slots can be described as defined in 3GPP technical specification (TS) 38.211, TS 38.213, and/or TS 38.214. Throughout this disclosure reference to TS 38.211, TS 38.212, TS 38.213, TS 38.214 is associated with version 16.4.0 of the 3GPP specifications.

[0037] Several solutions to provide variable resource timing and size are described below. According to a possible embodiment, one or more elements or features from one or more of the described solutions may be combined.

[0038] Figure 2 illustrates an example of a protocol stack 200, in accordance with aspects of the present disclosure. In certain embodiments, the protocol stack 200 is an NR protocol stack for communication between the UE and the mobile network. While Figure 2 shows a UE 206, a RAN node 208, and a 5G core network (5GC) 210 (e.g., comprising at least an AMF), these are representative of a set of UEs 104 interacting with an NE 102 (e.g., base station) and a CN 106.

[0039] As depicted, the protocol stack 200 comprises a UP protocol stack 202 and a CP protocol stack 204. The UP protocol stack 202 includes a physical (PHY) layer 212, a MAC sublayer 214, a radio link control (RLC) sublayer 216, a packet data convergence protocol (PDCP) sublayer 218, and a service data adaptation protocol (SDAP) layer 220. The CP protocol stack 204 includes a PHY layer 212, a MAC sublayer 214, a RLC sublayer 216, and a PDCP sublayer 218. The CP protocol stack 204 also includes a radio resource control (RRC) layer 222 and a non-access stratum (NAS) layer 224.

[0040] The AS layer 226 (also referred to as "AS protocol stack") for the UP protocol stack 202 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The AS layer 228 for the CP protocol stack 204 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The layer-1 (L1) includes the PHY layer 212. The layer-2 (L2) is split into the SDAP sublayer 220, PDCP sublayer 218, RLC sublayer 216, and MAC sublayer 214. The layer-3 (L3) includes the RRC layer 222 and the NAS layer 224 for the CP and includes, e.g., an internet protocol (IP) layer and/or PDU Layer (not depicted) for the UP. L1 and L2 are referred to as "lower layers," while L3 and above (e.g., transport layer, application layer) are referred to as "higher layers" or "upper layers."

[0041] The PHY layer 212 offers transport channels to the MAC sublayer 214. The PHY layer 212 may perform a beam failure detection procedure using energy detection thresholds, as described herein. In certain embodiments, the PHY layer 212 may send an indication of beam failure to a MAC entity at the MAC sublayer 214. The MAC sublayer 214 offers logical channels to the RLC sublayer 216. The RLC sublayer 216 offers RLC channels to the PDCP sublayer 218. The PDCP sublayer 218 offers radio bearers to the SDAP sublayer 220 and/or RRC layer 222. The SDAP sublayer 220 offers QoS flows to the core network (e.g., 5GC). The RRC layer 222 provides for the addition, modification, and release of carrier aggregation and/or dual connectivity.

The RRC layer 222 also manages the establishment, configuration, maintenance, and release of signaling radio bearers (SRBs) and data radio bearers (DRBs).

[0042] The NAS layer 224 is between the UE 206 and an AMF in the 5GC 210. NAS messages are passed transparently through the RAN. The NAS layer 224 is used to manage the establishment of communication sessions and for maintaining continuous communications with the UE 206 as it moves between different cells of the RAN. In contrast, the AS layers 226 and 228 are between the UE 206 and the RAN (i.e., RAN node 208) and carry information over the wireless portion of the network. While not depicted in Figure 2, the IP layer exists above the NAS layer 224, a transport layer exists above the IP layer, and an application layer exists above the transport layer.

[0043] The MAC sublayer 214 is the lowest sublayer in the L2 architecture of the protocol stack 200. Its connection to the PHY layer 212 below is through transport channels, and the connection to the RLC sublayer 216 above is through logical channels. The MAC sublayer 214 therefore performs multiplexing and demultiplexing between logical channels and transport channels: the MAC sublayer 214 in the transmitting side constructs MAC PDUs (also known as transport blocks (TBs)) from MAC service data units (SDUs) received through logical channels, and the MAC sublayer 214 in the receiving side recovers MAC SDUs from MAC PDUs received through transport channels.

[0044] The MAC sublayer 214 provides a data transfer service for the RLC sublayer 216 through logical channels, which are either control logical channels which carry control data (e.g., RRC signaling) or traffic logical channels which carry UP data. On the other hand, the data from the MAC sublayer 214 is exchanged with the PHY layer 212 through transport channels, which are classified as uplink (UL) or DL. Data is multiplexed into transport channels depending on how it is transmitted over the air.

[0045] The PHY layer 212 is responsible for the actual transmission of data and control information via the air interface, i.e., the PHY layer 212 carries all information from the MAC transport channels over the air interface on the transmission side. Some of the important functions performed by the PHY layer 212 include coding and modulation, link adaptation (e.g., adaptive modulation and coding (AMC)), power control, cell search and random access (for initial synchronization and handover purposes) and other measurements (inside the 3GPP system (i.e., NR and/or LTE system) and between systems) for the RRC layer 222. The PHY layer 212 performs transmissions based on transmission parameters, such as the modulation scheme, the coding rate (i.e., the modulation and coding scheme (MCS)), the number of physical resource blocks (PRBs), etc.

[0046] Note that an LTE protocol stack may comprise a similar structure to the protocol stack 200, with the differences that the LTE protocol stack lacks the SDAP sublayer 220 in the AS layer 226, that an EPC replaces the 5GC 210, and that the NAS layer 224 is between the UE 206 and an MME in the EPC. Also note that the present disclosure distinguishes between a protocol layer (such as the aforementioned PHY layer 212, MAC sublayer 214, RLC sublayer 216, PDCP sublayer 218, SDAP sublayer 220, RRC layer 222 and NAS layer 224) and a transmission layer in multiple-input multiple-output (MIMO) communication (also referred to as a "MIMO layer" or a "data stream").

[0047] In various embodiments, two or more UEs 206 may communicate directly with each other (e.g., device-to-device communication) using SL communication. The SL communication may comprise one or more SL channels, such as the physical sidelink control channel (PSCCH), the PSSCH, and/or the PSFCH. Here, SL transmissions may occur on SL resources. A UE 206 may be provided with different SL communication resources according to different allocation modes. For example, in 3GPP systems, allocation Mode-1 corresponds to a NR-based network-scheduled SL communication mode, wherein the in-coverage RAN indicates resources for use in SL operation, including resources of one or more resource pools. Allocation Mode-2 corresponds to a NR-based UE-scheduled SL communication mode (i.e., UE-autonomous selection), where the UE 206 selects a resource pools and resources therein from a set of candidate pools. Allocation Mode-3 corresponds to an LTE-based network-scheduled SL communication mode. Allocation Mode-4 corresponds to an LTE-based UE-scheduled SL communication mode (i.e., UE-autonomous selection).

[0048] As used herein, a "resource pool" refers to a set of resources assigned for SL operation. A resource pool consists of a set of RBs (i.e., physical resource blocks (PRBs)) over one or more time units (e.g., subframe, slots, orthogonal frequency division multiplexing (OFDM) symbols). In some embodiments, the set of RBs comprises contiguous PRBs in the frequency domain. A physical resource block (PRB), as used herein, consists of twelve consecutive subcarriers in the frequency domain.

[0049] Figure 3 depicts a SL protocol stack 300, in accordance with aspects of the present disclosure. While Figure 3 shows a transmitting SL UE 302 (denoted "Tx UE") and a receiving SL UE 304 (denoted "Rx UE"), these are representative of a set of UEs communicating peer-to-peer via a PC5 interface and other embodiments may involve different UEs. Each of the SL UE 302 and the SL UE 304 may be implementations of the UE 206 and/or UE 104, described above.

[0050] As depicted, the SL protocol stack 300 includes a physical layer 306, a MAC sublayer 308, a RLC sublayer 310, a PDCP sublayer 312, and RRC and SDAP layers (depicted as combined element "RRC/SDAP" 314), for the CP and UP, respectively. The physical layer 306, the MAC sublayer 308, the RLC sublayer 310, the PDCP sublayer 312, and the RRC / SDAP layers 314 may perform substantially the same functions described above with reference to the protocol stack 200 but supporting UE-to-UE communications between the SL UE 302 and the SL UE 304.

[0051] The AS protocol stack for the CP in the SL protocol stack 300 consists of at least RRC, PDCP, RLC and MAC sublayers, and the physical layer. The AS protocol stack for the UP in the SL protocol stack 300 consists of at least SDAP, PDCP, RLC and MAC sublayers, and the physical layer. The L2 is split into the SDAP, PDCP, RLC and MAC sublayers. The L3 includes the RRC sublayer and the NAS layer for the CP and includes, e.g., an IP layer for the UP. L1 and L2 are referred to as "lower layers", while L3 and above (e.g., transport layer, V2X layer, application layer) are referred to as "higher layers" or "upper layers."

[0052] In various embodiments, upon receiving an SL transmission, i.e., PSSCH transmission, from the SL UE 302, the SL UE 304 prepares Hybrid Automatic Repeat Request (HARQ) feedback (i.e., HARQ-ACK information) corresponding to the reception of the PSSCH transmission. The SL UE 304 then transmits a PSFCH transmission containing the HARQ feedback to the SL UE 302 (i.e., which transmitted the PSSCH transmission). As described in greater detail below, the SL UE 304 may adjust a priority level of the PSFCH transmission containing HARQ feedback, e.g., to ensure timely delivery of the HARQ feedback.

[0053] For SL unicast transmission, an Rx UE sends ACK to the Tx UE if the Rx UE has successfully decoded the TB carried in a PSSCH; otherwise, the Rx UE sends NACK to the Tx UE if the Rx UE has not decoded the TB after decoding the 1st-stage SCI. For SL groupcast transmissions, two HARQ options (HARQ option 1 and HARQ option 2) are supported for the SL HARQ feedback in NR V2X (note that V2X communication encompasses both vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication). For HARQ option 1, the Rx UE transmits NACK if the Rx UE has not successfully decoded the TB (after decoding the 1st-stage SCI) and if its relative distance to the Tx UE (referred as Tx-Rx distance) is less than or equal to the required communication range (indicated in the 2nd-stage SCI). Otherwise, the Rx UE does not transmit any HARQ feedback. As the HARQ feedback for this option would only consist of NACK, HARQ option 1 is referred to as NACK-only feedback. The transmission of HARQ-ACK, i.e., ACK or NACK, may further be enabled or disabled by a field in a control information, such as HARQ feedback enabled/disabled indicator field in an SCI format 2-A, or SCI format 2-B, or SCI format 2-C (e.g., as defined in 3GPP TS 38.212).

[0054] The PSFCH symbol that can be used for the HARQ feedback for a given PSSCH transmission corresponds to the PSFCH symbol in the first slot with PSFCH after a configured (or pre-configured) number of *K* slots after the PSSCH transmission (i.e., carrying the TB). Here, the parameter *K* represents the minimum number of slots within the resource pool between a slot with a PSSCH transmission and the slot containing PSFCH for the HARQ feedback of this transmission. Consider that the last symbol of a PSSCH transmission is on slot n. The HARQ feedback for this transmission is expected in slot $n + a$, where a is the smallest integer equal to or higher than K such that slot $n + a$ contains PSFCH.

[0055] For example, if the earliest possible slot for the HARQ feedback (slot $n+a$) does not contain PSFCH, then the HARQ feedback is sent at the next slot containing PSFCH (i.e., after slot $n+a$). The time gap of at least *K* slots allows considering the Rx UE's processing delay in decoding the PSCCH and generating the HARQ feedback. *K* can be equal to 2 or 3, and a single value of *K* can be configured (or pre-configured) per resource pool. This allows several Rx UEs using the same resource pool to utilize the same mapping of PSFCH resource(s) for the HARQ feedback. With the parameter *K*, the *N* PSSCH slots associated with a slot with PSFCH can be determined. In an example with $K=3$, the $N=4$ PSSCH slots associated with the PSFCH transmission instances at slot $n+6$ correspond to PSSCH slots n, $n+1$, $n+2$, and $n+3$.

[0056] With L sub-channels in a resource pool and N PSSCH slots associated with a slot containing PSFCH, there are then N times L sub-channels associated with a PSFCH symbol. With M PRBs available for PSFCH in a PSFCH symbol, there are M PRBs available for the HARQ feedback of transmissions over N times L sub-channels. With M configured to be a multiple of N times L, then a distinct set of $M_{set} = M/(N \cdot L)$ PRBs can be associated with the HARQ feedback for each sub-channel within a PSFCH period.

[0057] The first set of M_{set} PRBs among the M PRBs available for PSFCH are associated with the HARQ feedback of a transmission in the first sub-channel in the first slot. The second set of M_{set} PRBs are associated with the HARQ feedback of a transmission in the first sub-channel in the second slot and so on. For example, if $N = 4$, $L = 3$ and with all PRBs in a PSFCH symbol available for PSFCH, the HARQ feedback for a transmission at PSSCH x is sent on the set x of M_{set} PRBs in the corresponding PSFCH symbol, with x=1,…,12. For a transmission in a PSSCH with

L_{PSSCH}>1 sub-channels, L_{PSSCH} times M_{set} PRBs could be available for the HARQ feedback of this transmission.

[0058] A set of M_{set} PRBs associated with a sub-channel are shared among multiple Rx UEs in case of HARQ-ACK feedback for groupcast communications (HARQ option 2) or in the case of different PSSCH transmissions in the same sub-channel. For each PRB available for PSFCH, there are Q cyclic shift pairs available to support the ACK or NACK feedback of Q Rx UEs within the PRB. For a resource pool, the number of cyclic shift pairs Q is configured (or pre-configured) and can be equal to 1, 2, 3 or 6.

[0059] With each PSFCH used by one Rx UE, F available PSFCH transmission instances can be used for the HARQ-ACK feedback of up to F Rx UEs. The F PSFCH transmission instances can be determined based on two options: either based on the L_{PSSCH} sub-channels used by a PSSCH or based only on the starting sub-channel used by a PSSCH (i.e., based only on one sub-channel for the case when L_{PSSCH} >1). Thus, F can be computed based on: (i) L_{PSSCH} sub-channels of a PSSCH; (ii) M_{set} PRBs for PSFCH associated with each sub-channel; and (iii) Q cyclic shift pairs available in each PRB.

[0060] Depending on which of two supported HARQ feedback options is configured (or pre-configured), there are either then $F= L_{\text{PSSCH}} \cdot M_{\text{set}} \cdot Q$ PSFCH transmission instances (associated with the L_{PSSCH} sub-channels of a PSSCH) or $F= M_{\text{set}} \cdot Q$ PSFCH transmission instances (associated with the starting sub-channel of a PSSCH) available for multiplexing the HARQ feedback for the PSSCH.

[0061] Similar to the physical uplink control channel (PUCCH) in 3GPP release 15 (Rel-15) NR on the Uu interface, the F available PSFCH transmission instances are indexed based on a PRB index (frequency domain) and a cyclic shift pair index (code domain). Depending on the configured (or pre-configured) option, there are either $L_{\text{PSSCH}} \cdot M_{\text{set}}$ or M_{set} PRBs available for PSFCH. The mapping of the PSFCH index i (i=1,2,…,F) to the $L_{\text{PSSCH}} \cdot M_{\text{set}}$ or M_{set} PRBs and to the Q cyclic shift pairs is such that the PSFCH index i first increases with the PRB index until reaching the number of available PRBs for PSFCH (i.e., $L_{\text{PSSCH}} \cdot M_{\text{set}}$ or M_{set}). Then, the PSFCH index i increases with the cyclic shift pair index, again with the PRB index and so on.

[0062] Due to implementation constraints a UE indicates a capability by parameter *psfch-FormatZeroSidelink* (e.g., defined in 3GPP TS 38.331 and TS 38.306) if the UE is capable of transmitting PSFCH format 0 over the SL; in this case, the UE further indicates by parameter *psfch-TxNumber* (e.g., defined in TS 38.331 and TS 38.306) the number of PSFCH(s) resources that the UE can transmit in a slot ($N_{\text{max,PSFCH}}$). As of NR Rel-17, this can indicate 4, 8, or 16 PSFCH transmission instances per slot.

[0063] However, it is possible that the number of scheduled PSFCH transmission instances $N_{\text{sch,Tx,PSFCH}}$ exceeds the indicated maximum $N_{\text{Max,PSFCH}}$. To resolve this case, 3GPP TS 38.213 v17.2.0 defines the following in clause 16.2.3:

[0064] If *dl-P0-PSFCH* is provided, and if $N_{\text{sch,Tx,PSFCH}} \leq N_{\text{max,PSFCH}}$ (i.e., if the number of scheduled PSFCH transmission instances is less than the indicated maximum), then $N_{\text{Tx,PSFCH}} = N_{\text{sch,Tx,PSFCH}}$ and $P_{\text{PSFCH,k}}(i) = P_{\text{PSFCH,one}}$ [dBm] when $P_{\text{PSFCH,one}} + 10log_{10}\left(N_{\text{sch,Tx,PSFCH}}\right) \leq P_{\text{CMAX}}$, where P_{CMAX} is determined for $N_{\text{sch,Tx,PSFCH}}$ PSFCH transmissions, e.g., according to 3GPP TS 38.101.

[0065] Else, (i.e., if there is insufficient power to transmit all scheduled PSFCH transmission instances), then the UE autonomously determines $N_{\text{Tx,PSFCH}}$ PSFCH transmissions first with ascending order of corresponding priority field values (e.g., as described in clause 16.2.4.2 of 3GPP TS 38.213) over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH transmissions with conflict information, if any, such that $N_{\text{Tx,PSFCH}} \geq \max(1, \sum_{i=1}^{K} M_i)$ where M_i, for $1 \leq i \leq 8$, is a number of PSFCH transmission instances with priority value i for PSFCH with HARQ-ACK information and M_i, for $i > 8$, is a number of PSFCH transmission instances with priority value $i - 8$ for PSFCH with conflict information and K is defined as the largest value satisfying $P_{\text{PSFCH,one}} + 10log_{10}(\max(1, \sum_{i=1}^{K} M_i)) \leq P_{\text{CMAX}}$ where P_{CMAX} is determined according to 3GPP TS 38.101 for transmission of all PSFCH transmission instances in $\sum_{i=1}^{K} M_i$, if any, and zero, otherwise, and $P_{\text{PSFCH,k}}(\text{i}) = \min(P_{\text{CMAX}} - 10log_{10}(N_{\text{Tx,PSFCH}}), P_{\text{PSFCH,one}})$ [dBm] where P_{CMAX} is defined in 3GPP TS 38.101 and is determined for the $N_{\text{Tx,PSFCH}}$ PSFCH transmissions.

[0066] Else (i.e., if there are more scheduled PSFCH transmission instances than the indicated maximum), the UE autonomously selects $N_{\text{max,PSFCH}}$ PSFCH transmissions with ascending order of corresponding priority field values (e.g., as described in clause 16.2.4.2 of 3GPP TS 38.213). If $P_{\text{PSFCH,one}} + 10log_{10}\left(N_{\text{max,PSFCH}}\right) \leq P_{\text{CMAX}}$, where P_{CMAX} is determined for the $N_{\text{max,PSFCH}}$ PSFCH transmissions (e.g., according to 3GPP TS 38.101), then $N_{\text{Tx,PSFCH}} = N_{\text{max,PSFCH}}$ and $P_{\text{PSFCH,k}}(i) = P_{\text{PSFCH,one}}$ [dBm].

[0067] Else (i.e., there is insufficient power to transmit the indicated maximum number of PSFCH transmission instances), the UE autonomously selects $N_{\text{Tx,PSFCH}}$ PSFCH transmissions in ascending order of corresponding priority field values (e.g., as described in clause 16.2.4.2 of 3GPP TS 38.213) over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH transmissions with conflict information, if any, such that $N_{\mathrm{Tx,PSFCH}} \geq \max(1, \sum_{i=1}^{K} M_i)$ where M_i, $1 \leq i \leq 8$, is a number of PSFCH transmission instances with priority value i for PSFCH with HARQ-ACK information and M_i, $i > 8$, is a number of PSFCH transmission instances with priority value $i - 8$ for PSFCH with conflict information and K is defined as the largest value satisfying $P_{\mathrm{PSFCH,one}} + 10log_{10}(\max(1, \sum_{i=1}^{K} M_i)) \leq P_{\mathrm{CMAX}}$ where P_{CMAX} is determined (e.g., according to 3GPP TS 38.101-1) for transmission of all PSFCH transmission instances in $\sum_{i=1}^{K} M_i$, if any, and zero, otherwise, and $P_{\mathrm{PSFCH,k}}(i) = \min(P_{\mathrm{CMAX}} - 10log_{10}(N_{\mathrm{Tx,PSFCH}}), P_{\mathrm{PSFCH,one}})$ [dBm] where P_{CMAX} is determined for the $N_{\mathrm{Tx,PSFCH}}$ simultaneous PSFCH transmissions, e.g., according to 3GPP TS 38.101.

[0068] Else, $P_{\mathrm{PSFCH,k}}(i) = P_{\mathrm{CMAX}} - 10log_{10}(N_{\mathrm{Tx,PSFCH}})$ [dBm] where the UE autonomously determines $N_{\mathrm{Tx,PSFCH}}$ PSFCH transmissions with ascending order of corresponding priority field values as described in clause 16.2.4.2 over the PSFCH transmissions with HARQ-ACK information, if any, and then with ascending order of priority value over the PSFCH transmissions with conflict information, if any, such that $N_{\mathrm{Tx,PSFCH}} \geq 1$ and where P_{CMAX} is determined for the $N_{\mathrm{Tx,PSFCH}}$ PSFCH transmissions according to 3GPP TS 38.101.

[0069] Regarding simultaneous PSFCH transmission/reception, for a PSFCH transmission or reception with HARQ-ACK information, a priority value for the PSFCH is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH.

[0070] For PSFCH transmission with conflict information, a priority value for the PSFCH is equal to the smallest priority value determined by the corresponding SCI formats 1-A for the conflicting resources.

[0071] For PSFCH reception with conflict information, a priority value for the PSFCH is equal to the priority value determined by the corresponding SCI format 1-A for the conflicting resource.

[0072] If a UE would transmit $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances and receive $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH transmission instances, and transmissions of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances would overlap in time with receptions of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH transmission instances, then the UE transmits or receives only a set of PSFCH transmission instances corresponding to the smallest priority field value, as determined by a first set of SCI format 1-A and/or a second set of SCI format 1-A (e.g., as defined in 3GPP TS 38.212) that are respectively associated with PSFCH transmission instances with HARQ-ACK information from the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances and PSFCH transmission instances with HARQ-ACK information from the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH transmission instances when one or more of the PSFCH transmission instances provide HARQ-ACK information.

[0073] If none of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances and none of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH transmission instances provide HARQ-ACK information, the UE transmits or receives only a set of PSFCH transmission instances corresponding to the smallest priority value of the first set of PSFCH transmission instances and the second set of PSFCH transmission instances that are respectively associated with the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances and the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH transmission instances when the PSFCH transmission instances provide conflict information..

[0074] If a UE would transmit $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH transmission instances in a PSFCH transmission occasion, the UE first transmits PSFCH transmission instances with HARQ-ACK information from $N_{\mathrm{Tx,PSFCH}}$ PSFCH transmission instances corresponding to the smallest priority field values from the $N_{\mathrm{Tx,PSFCH}}$ priority field values. Subsequently, the UE transmits remaining PSFCH transmission instances with conflict information corresponding to the smallest remaining priority field values from the $N_{\mathrm{Tx,PSFCH}}$ priority field values, if any.

[0075] If a UE indicates a capability to receive $N_{\mathrm{Rx,PSFCH}}$ PSFCH transmission instances in a PSFCH reception occasion (e.g., as defined in 3GPP TS 38.306), the UE first receives PSFCH transmission instances with HARQ-ACK information, if any, and subsequently receives PSFCH transmission instances with conflict information, if any.

[0076] Regarding the UE procedure for transmitting PSFCH with control information, a UE can be indicated by an SCI format scheduling a PSSCH reception to transmit a PSFCH with HARQ-ACK information in response to the PSSCH reception. For the PSFCH, in one embodiment, the UE provides HARQ-ACK information that includes ACK or NACK. In another embodiment, the UE provides HARQ-ACK information that includes only NACK.

[0077] A UE can be provided, by parameter *sl-PSFCH-Period*, a number of slots in a resource pool for a period of PSFCH transmission occasion resources. If the number is zero, then PSFCH transmissions from the UE in the resource pool are disabled.

[0078] A UE can be enabled, by parameter *inter-UECoordinationScheme2*, to transmit a PSFCH with conflict information in a resource pool. The UE can determine, based on an indication by a SCI format 1-A, a set of resources that includes one or more slots and RBs that are reserved for PSSCH transmission. If the UE determines a conflict for a reserved resource for PSSCH transmission, then the UE provides conflict information in a PSFCH.

[0079] A UE expects that a slot t'^{SL}_{k} $(0 \leq k < T'_{max})$ has a PSFCH transmission occasion resource if k mod $N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}} = 0$, where t'^{SL}_{k} is defined in 3GPP TS 38.214), and T'_{max} is a number of slots that belong to the resource pool within 10240 msec according to 3GPP TS 38.214), and $N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}$ is provided by parameter *sl-PSFCH-Period.*

[0080] A UE may be indicated by higher layers to not transmit a PSFCH that includes HARQ-ACK information in response to a PSSCH reception (e.g., as described in 3GPP TS 38.321).

[0081] If a UE receives a PSSCH in a resource pool and the HARQ feedback enabled/disabled indicator field in an associated SCI format 2-A/2-B/2-C has value 1 (e.g., as defined in 3GPP TS 38.212), then the UE provides the HARQ-ACK information in a PSFCH transmission in the resource pool. The UE transmits the PSFCH in a first slot that includes PSFCH resources and is at least a number of slots, provided by parameter *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of the PSSCH reception.

[0082] A UE is provided by parameter *sl-PSFCH-RB-Set* a set of $M_{\mathrm{PRB,\,set}}^{\mathrm{PSFCH}}$ PRBs in a resource pool for PSFCH transmission with HARQ-ACK information in a PRB of the resource pool. A UE can be provided by parameter *sl-PSFCH-Conflict-RB-Set* a set of $M_{\mathrm{PRB,\,set}}^{\mathrm{PSFCH}}$ PRBs in a resource pool for PSFCH transmission with conflict information in a PRB of the resource pool. A UE expects that different PRBs are configured (or pre-configured) for conflict information and HARQ-ACK information.

[0083] For a number of N_{subch} sub-channels for the resource pool, provided by parameter *sl-NumSubchannel*, and a number of PSSCH slots associated with a PSFCH slot that is less than or equal to $N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}$, the UE allocates the $\left[\left(i + j \cdot N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}\right) \cdot M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}}, \left(i + 1 + j \cdot N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}\right) \cdot M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}} - 1\right]$ PRBs from the $M_{\mathrm{PRB,\,set}}^{\mathrm{PSFCH}}$ PRBs to slot i among the PSSCH slots associated with the PSFCH slot and sub-channel j, where $M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}} = M_{\mathrm{PRB,\,set}}^{\mathrm{PSFCH}} / \left(N_{\mathrm{subch}} \cdot N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}\right)$, $0 \leq i < N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}$, $0 \leq j < N_{\mathrm{subch}}$, and the allocation starts in an ascending order of i and continues in an ascending order of j. The UE expects that $M_{\mathrm{PRB,\,set}}^{\mathrm{PSFCH}}$ is a multiple of $N_{\mathrm{subch}} \cdot N_{\mathrm{PSSCH}}^{\mathrm{PSFCH}}$.

[0084] The second OFDM symbol l' of PSFCH transmission in a slot is defined as $l' = sl\text{-}StartSymbol + sl\text{-}LengthSymbols - 2$.

[0085] A UE determines a number of PSFCH resources available for multiplexing HARQ-ACK or conflict information in a PSFCH transmission as $R_{\mathrm{PRB,\,CS}}^{\mathrm{PSFCH}} = N_{\mathrm{type}}^{\mathrm{PSFCH}} \cdot M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}} \cdot N_{\mathrm{CS}}^{\mathrm{PSFCH}}$ where $N_{\mathrm{CS}}^{\mathrm{PSFCH}}$ is a number of cyclic shift (CS) pairs for the resource pool provided by parameter *sl-NumMuxCS-Pair* and, based on an indication by parameter *sl-PSFCH-CandidateResourceType*.

[0086] If parameter *sl-PSFCH-CandidateResourceType* is configured as *startSubCH*, then $N_{\mathrm{type}}^{\mathrm{PSFCH}} = 1$ and the $M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}}$ PRBs are associated with the starting sub-channel of the corresponding PSSCH. If parameter *sl-PSFCH-CandidateResourceType* is configured as *allocSubCH*, then $N_{\mathrm{type}}^{\mathrm{PSFCH}} = N_{\mathrm{subch}}^{\mathrm{PSSCH}}$ and the $N_{\mathrm{subch}}^{\mathrm{PSSCH}} \cdot M_{\mathrm{subch,\,slot}}^{\mathrm{PSFCH}}$ PRBs are associated with the $N_{\mathrm{subch}}^{\mathrm{PSSCH}}$ sub-channels of the corresponding PSSCH. For conflict information, the corresponding PSSCH is determined based on parameters *PSFCHOccasionScheme2*.

[0087] Regarding channel access procedures for UL transmission(s), a UE is to use Type 1 channel access procedures for transmitting sounding reference signal (SRS) transmission not including a PUSCH transmission. The UE is to use UL channel access priority class (CAPC) p = 1 for SRS transmissions not including a PUSCH transmission. When a UE uses Type 1 channel access procedures for PUCCH transmissions or PUSCH only transmissions without UL-SCH, then the UE is to use UL CAPC p = 1.

[0088] A UE is to use Type 1 channel access procedure for PRACH transmissions and PUSCH transmissions without user plane data related to random access procedure that initiate a channel occupancy. In this case, UL CAPC p = 1 is used for PRACH transmissions, and UL CAPC used for PUSCH transmissions is determined according to clause 5.6.2 in 3GPP TS 38.300.

[0089] When a UE uses Type 1 channel access procedures for PUSCH transmissions on configured resource, the UE determines the corresponding UL channel access priority p in Table 1 following the procedures described in clause 5.6.2 in 3GPP TS 38.300.

[0090] When a UE uses Type 1 channel access procedures for PUSCH transmissions with user plane data indicated by a UL grant or related to random access procedure where the corresponding UL channel access priority p is not indicated, the UE determines the channel access priority p using in Table 1 (below) following the same procedures as for PUSCH transmission on configured resources using Type 1 channel access procedures.

[0091] A UE is not to transmit on a channel for a channel occupancy time (COT) that exceeds $T_{ulmcot,p}$ where the channel access procedure is performed based on the CAPC p associated with the UE transmissions, as given in Table 1.

[0092] The total COT of autonomous uplink transmission(s) obtained by the channel access procedure, including the following DL transmission if the UE sets 'COT sharing indication' in AUL-UCI to '1' in a subframe within the autonomous uplink transmission(s) as described in clause 4.1.3 of 3GPP TS 37.213, shall not exceed $T_{ulmcot,p}$, where $T_{ulmcot,p}$ is given in Table 1.

[0093] UL CAPCs are shown below in Table 1. Note that the variable $CW_{min,p}$ represents the minimum CW size for the class, while the variable $CW_{max,p}$ represents the maximum CW size for the class.

Channel Access Priority Class (p)	m_p	$CW_{min,p}$	$CW_{max,p}$	$T_{ulm\,cot,p}$	**allowed CW_p sizes**
1	2	3	7	2 ms	{3,7}
2	2	7	15	4 ms	{7,15}
3	3	15	1023	6ms or 10 ms	{15,31,63,127,255,511,1023}
4	7	15	1023	6ms or 10 ms	{15,31,63,127,255,511,1023}
NOTE1: For $p = 3,4$, $T_{ulm\,cot,p} = 10ms$ if the higher layer parameter *absenceOfAnyOtherTechnology-r14* or *absenceOfAnyOtherTechnology*-r16 is provided, otherwise, $T_{ulm\,cot,p} = 6ms$. NOTE 2: When $T_{ulm\,cot,p} = 6ms$ it may be increased to $8ms$ by inserting one or more gaps. The minimum duration of a gap shall be $100us$. The maximum duration before including any such gap shall be $6ms$.					

Table 1: CAPC for UL

[0094] The Type 1 UL channel access procedure may be performed by a UE where the time duration spanned by the sensing slots that are sensed to be idle before a UL transmission(s) is random. The Type 1 UL channel access procedure is applicable to the following transmissions: PUSCH/SRS transmission(s) scheduled or configured by eNB/gNB, or PUCCH transmission(s) scheduled or configured by gNB, or Transmission(s) related to random access procedure.

[0095] A UE may transmit the applicable transmission using Type 1 channel access procedure after first sensing the channel to be idle during the slot durations of a defer duration T_d, and after the counter N is zero in step 4. The counter N is adjusted by sensing the channel for additional slot duration(s) according to the steps described below.

[0096] Step 1, set $N = N_{init}$, where N_{init} is a random number uniformly distributed between 0 and CW_p, and go to step 4.

[0097] Step 2, if $N > 0$ and the UE chooses to decrement the counter, set $N = N - 1$.

[0098] Step 3, sense the channel for an additional slot duration, and if the additional slot duration is idle, go to step 4; else, go to step 5.

[0099] Step 4, if $N = 0$, stop; else, go to step 2.

[0100] Step 5, sense the channel until either a busy slot is detected within an additional defer duration *Td* or all the slots of the additional defer duration *Td* are detected to be idle.

[0101] Step 6, if the channel is sensed to be idle during all the slot durations of the additional defer duration *Td*, go to step 4; else, go to step 5.

[0102] If a UE has not transmitted a UL transmission on a channel on which UL transmission(s) are performed after Step 4 in the procedure above, then the UE may transmit a transmission on the channel, if the channel is sensed to be idle at least in a sensing slot duration *Tsl* when the UE is ready to transmit the transmission and if the channel has been sensed to be idle during all the slot durations of a defer duration *Td* immediately before the transmission.

[0103] If the channel has not been sensed to be idle in a sensing slot duration *Tsl* when the UE first senses the channel after it is ready to transmit, or if the channel has not been sensed to be idle during any of the sensing slot durations of a defer duration *Td* immediately before the intended transmission, the UE proceeds to Step 1 after sensing the channel to be idle during the slot durations of a defer duration *Td*.

[0104] The defer duration *Td* consists of duration $T_f = 16\mu s$ immediately followed by m_p consecutive slot durations where each slot duration is $T_{sl} = 9\mu s$, and T_f includes an idle slot duration *Tsl* at start of *Tf*.

[0105] $CW_{min,p} \leq CW_p \leq CW_{max,p}$ is the contention window. CW_p adjustment is described below. $CW_{min,p}$ and $CW_{max,p}$ are chosen before step 1 of the procedure above. The values of m_p, $CW_{min,p}$, and $CW_{max,p}$ are based on a channel access priority class p as shown in Table 1, that is signaled to the UE.

[0106] If a UE transmits transmissions using Type 1 channel access procedures that are associated with channel access priority class p on a channel, the UE maintains the CW value CW_p and adjusts CW_p for those transmissions before step 1 of the above described Type 1 UL channel access procedure.

[0107] Regarding the CW adjustment procedures for UL transmissions scheduled/configured by gNB, if a UE transmits transmissions using Type 1 channel access procedures that are associated with channel access priority class p on a channel, the UE maintains the CW value CW_p and adjusts CW_p for those transmissions before step 1 of the above described Type 1 UL channel access procedure, using the following steps:

[0108] Step 1, for every priority class $p \in \{1,2,3,4\}$, set $CW_p = CW_{min,p}$.

[0109] Step 2, if HARQ-ACK feedback is available after the last update of CW_p, go to step 3. Otherwise, if the UE transmission after the above described Type 1 UL channel access procedure does not include a retransmission or is transmitted within a duration T_w from the end of the *reference duration* corresponding to the earliest UL channel occupancy after the last update of CW_p, go to step 5; otherwise go to step 4.

[0110] Step 3, the HARQ-ACK feedback(s) corresponding to PUSCH(s) in the *reference duration* for the latest UL channel occupancy for which HARQ-ACK feedback is available is used as follows: If at least one HARQ-ACK feedback is 'ACK' for PUSCH(s) with TB-based feedback or at least 10% of HARQ-ACK feedbacks are 'ACK' for PUSCH code block groups (CBGs) transmitted at least partially on the channel with CBG-based feedback, go to step 1; otherwise go to step 4.

[0111] Step 4, increase CW_p for every priority class $p \in \{1,2,3,4\}$ to the next higher allowed value.

[0112] Step 5, for every priority class $p \in \{1,2,3,4\}$, maintain CW_p as it is; go to step 2.

[0113] The HARQ-ACK feedback, *reference duration* and duration T_w in the procedure above are defined as the following:

[0114] For the purpose of CW adjustment in this clause, HARQ-ACK feedback for PUSCH(s) transmissions are expected to be provided to UE(s) explicitly or implicitly where explicit HARQ-ACK is determined based on the valid HARQ-ACK feedback in a corresponding CG-DFI as described in clause 10.5 of 3GPP TS 38.213, and implicit HARQ-ACK feedback is determined based on the indication for a new transmission or retransmission in the downlink control information (DCI) scheduling PUSCH(s) as follows:

[0115] If a new transmission is indicated, 'ACK' is assumed for the transport blocks or code block groups in the corresponding PUSCH(s) for the TB-based and CBG-based transmission, respectively.

[0116] If a retransmission is indicated for TB-based transmissions, 'NACK' is assumed for the transport blocks in the corresponding PUSCH(s).

[0117] If a retransmission is indicated for CBG-based transmissions, if a bit value in the code block group transmission information (CBGTI) field is '0' or '1' as described in clause 5.1.7.2 of 3GPP TS 38.214, 'ACK' or 'NACK' is assumed for the corresponding CBG in the corresponding PUSCH(s), respectively.

[0118] The *reference duration* corresponding to a channel occupancy initiated by the UE including transmission of PUSCH(s) is defined in this clause as a duration starting from the beginning of the channel occupancy until the end of the first slot where at least one PUSCH is transmitted over all the resources allocated for the PUSCH, or until the end of the first transmission burst by the UE that contains PUSCH(s) transmitted over all the resources allocated for the PUSCH, whichever occurs earlier. If the channel occupancy includes a PUSCH, but it does not include any PUSCH transmitted over all the resources allocated for that PUSCH, then, the duration of the first transmission burst by the UE within the channel occupancy that contains PUSCH(s) is the *reference duration* for CW size adjustment.

[0119] $T_w = \max(T_A, T_B + 1ms)$ where T_B is the duration of the transmission burst from start of the *reference duration* in ms and $T_A = 5ms$ if the absence of any other technology sharing the channel cannot be guaranteed on a long-term basis (e.g., by level of regulation), and $T_A = 10ms$ otherwise.

[0120] If a UE transmits transmissions using Type 1 channel access procedures associated with the channel access priority class p on a channel and the transmissions are not associated with explicit or implicit HARQ-ACK feedbacks as described above in this clause, the UE adjusts CW_p before step 1 in the above described Type 1 UL channel access procedure, using the latest CW_p used for any UL transmissions on the channel using Type 1 channel access procedures associated with the channel access priority class p. If the corresponding channel access priority class p has not been used for any UL transmission on the channel, $CW_p = CW_{min,p}$ is used.

[0121] Described herein are procedures and signaling between a Tx UE and an Rx UE via SL communication. The Tx UE is characterized by transmitting a data transmission via PSSCH scheduled by SCI (via PSCCH/PSSCH), and by receiving corresponding HARQ-ACK feedback (e.g., via PSFCH). The Rx UE is characterized by receiving a data transmission via PSSCH scheduled by a received SCI (via PSCCH/PSSCH), and by transmitting corresponding HARQ-ACK feedback (e.g., via PSFCH).

[0122] Beneficially, the solutions described herein establish that HARQ-ACK for transmissions within the reference duration are not subject to dropping because of a low priority. To this end, the corresponding HARQ-ACK transmissions are assigned a high priority with respect to channel access procedures described above.

[0123] In various embodiments, a UE increases the priority level of a PSFCH transmission. In some cases, the UE may intend to (i.e., be expected to) transmit $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs and receive $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs, and the transmissions of the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs would overlap in time with receptions of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs. Due to half-duplex constraints, the UE may need to make a determination whether to transmit the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCH (and therefore not receive $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCH) or to receive the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs (and therefore not transmit, i.e., drop, the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs). In such embodiments, the determination may be based on the smallest priority level in the corresponding sets of PSFCHs that would be transmitted and received. For example, if the smallest priority level for the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs is smaller than the smallest priority level of the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs, the UE determines to transmit the $N_{\mathrm{sch,Tx,PSFCH}}$ PSFCHs.

[0124] According to the solutions described herein, the priority levels for such a comparison are determined in accordance with the various embodiments. For example, if the priority level for a PSFCH transmission is adjusted to a value of 1 according to one of the embodiments, then the adjusted value is taken into account when determining the smallest priority level of the $N_{\mathrm{sch,Tx,PSFCH}}$ transmit PSFCHs and the $N_{\mathrm{sch,Rx,PSFCH}}$ PSFCHs.

[0125] As used herein, the SL reference duration is defined as a duration corresponding to a channel occupancy initiated by the UE including transmission of PSSCH(s), starting from the beginning of the channel occupancy initiated by the UE including transmission of PSSCH(s), until the end of the first slot where at least one PSSCH transmission with ACK/NACK HARQ-ACK enabled is transmitted. An alternative definition of the reference duration is that feedback for PSSCH(s) transmitted within the reference duration is used in a CW adjustment procedure.

[0126] Regarding channel access procedures for SL transmission(s), in various embodiments, a UE (e.g., the SL UE 302 and/or SL UE 304) may to use a Type 1 channel access procedure, without loss of generality, similar to those described above with reference to UL channel access procedures, for PSFCH transmission(s). Similarly, regarding CW adjustment procedures for SL transmission(s), without loss of generality, a UE may adjust the CW for PSFCH transmission(s) in accordance with the principles described above in relation to CW adjustment procedures for UL transmission(s).

[0127] As used herein, a PSFCH transmission instance refers to a SL transmission of information (e.g., HARQ feedback information) on the PSFCH. For example, a Tx UE may transmit data to a Rx UE on the PSSCH. Here, the Rx UE provides HARQ feedback information to the Tx UE via a PSFCH transmission instance. An alternative information conveyed on PSFCH in a PSFCH transmission instance may be conflict information, e.g., as specified in 3GPP TS 38.213 v17.4.0 clause 16.3.0. In the below descriptions the term "PSFCH transmission" refers to a PSFCH transmission instance, unless indicated otherwise.

[0128] Described in 3GPP TS 38.213, clause 16.2.3, 3GPP Rel-17 defines rules how to determine which PSFCH transmission instances to transmit, specifically including the case that the number of scheduled PSFCH transmissions, $N_{\mathrm{sch,Tx,PSFCH}}$, exceeds the indicated maximum of PSFCH transmissions, $N_{\mathrm{max,PSFCH}}$, or that there is insufficient power to transmit the number of scheduled PSFCH transmissions, $N_{\mathrm{sch,Tx,PSFCH}}$.

[0129] Simply speaking, the PSFCHs are sorted according to their associated priority values (e.g., in ascending order), and the UE will transmit up to the maximum (i.e., $N_{\mathrm{max,PSFCH}}$) of PSFCH transmissions with the lowest (i.e., smallest) associated priority values if there is sufficient transmit power available. Otherwise, the UE will transmit the maximum number of PSFCH transmissions – sorted according to the lowest associated priority values, starting from the lowest associated priority value – for which the total transmitted power is below P_{CMAX} (see clause 16.2.3 in 3GPP TS 38.213).

[0130] According to embodiments of a first solution, a UE may increase the priority level of a PSFCH transmission carrying HARQ-ACK information based on a transmission time of an associated PSSCH transmission. Specifically, for a PSFCH transmission or reception with HARQ-ACK information, if the PSSCH transmission associated with the PSFCH is transmitted within the SL reference duration (i.e., the feedback is relevant for CW adjustment), then the Rx UE sets a priority value for the PSFCH equal to 1. In one aspect, the Tx UE may assume that the corresponding PSFCH transmission by the Rx UE, i.e., the corresponding PSFCH reception from the Tx UE's perspective, is associated with an increased priority level (i.e., the priority value set to 1). In various embodiments, the lowest (i.e., smallest) priority value is 1, which also indicates the highest priority level.

[0131] Otherwise, if the PSSCH transmission associated with the PSFCH is not transmitted within the SL reference duration, then the priority value for the PSFCH follows legacy behavior and is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH. Note that the priority value indicated by the SCI format 1-A associated with the PSFCH may be 1; however, it is more likely that the indicated priority level will be greater than 1 (i.e., indicating a lower priority level). Accordingly, in one aspect of the first solution, the Rx UE may override a priority level/value signaled by SCI format 1-A when the PSFCH transmission carries HARQ-ACK information, and the feedback is relevant for CW adjustment.

[0132] According to embodiments of a second solution, a UE may increase the priority level of a PSFCH transmission carrying HARQ-ACK information (i.e., by setting the priority value for the PSFCH transmission to 1) only if the associated PSSCH transmission is transmitted in the same slot as the associated SCI. In one aspect, a Tx UE may assume that the corresponding PSFCH transmission by an Rx UE, i.e., the corresponding PSFCH reception from the Tx UE's perspective, is associated with an increased priority level (i.e., the priority value set to 1). However, the priority level is not modified when the PSFCH transmission is associated with PSSCH transmissions transmitted in future slots reserved/indicated by the associated SCI.

[0133] For example, the priority value of a PSFCH transmission, associated with a PSSCH transmitted in slot n_1 where the associated SCI is transmitted in slot n_1, may be set to 1; however the priority value of a PSFCH transmission associated with a PSSCH transmission transmitted in slot n_2 where the associated SCI is transmitted in slot n_1 (with $n_1 \neq n_2$) will be equal to the priority value indicated by the SCI format 1-A associated with the PSFCH transmission.

[0134] Thus, for a PSFCH transmission or reception with HARQ-ACK information, if the SCI (e.g., a 1st stage SCI format such as SCI format 1-A or a 2nd stage SCI format such as SCI formats 2-A, 2-B, 2-C) associated with the PSFCH transmission indicates that the PSSCH transmitted in the same slot as the SCI is within the reference duration (i.e., the feedback is relevant for CW adjustment), then the Rx UE sets the priority value for the PSFCH equal to 1 (i.e., lowest priority value and highest priority level).

[0135] Otherwise, if the SCI associated with the PSFCH transmission indicates that the PSSCH transmitted in the same slot as the SCI is not within the reference duration, then the priority value for the PSFCH transmission is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH transmission. Note that the priority value indicated by the SCI format 1-A associated with the PSFCH transmission may be 1; however, it is more likely that the indicated priority level will be greater than 1 (i.e., indicating a lower priority level). Accordingly, in one aspect of the second solution, the Rx UE may override a priority level/value signaled by SCI format

1-A when the SCI associated with the PSFCH transmission indicates that the PSSCH transmission transmitted in the same slot as the SCI is within the reference duration.

[0136] According to embodiments of a third solution, a UE may increase the priority level of a PSFCH transmission carrying HARQ-ACK information based on an explicit indication in SCI. Specifically, for a PSFCH transmission or reception with HARQ-ACK information, if the SCI (e.g., a 1st stage SCI format such as SCI format 1-A or a 2nd stage SCI format such as SCI formats 2-A, 2-B, 2-C) associated with the PSFCH transmission indicates that the PSSCH transmitted in the same slot as the SCI is within the reference duration (i.e., the feedback is relevant for CW adjustment), then the UE sets the priority value for the PSFCH equal to 1 (i.e., lowest priority value and highest priority level). In one aspect, the Tx UE may assume that the corresponding PSFCH transmission by the Rx UE, i.e., the corresponding PSFCH reception from the Tx UE's perspective, is associated with an increased priority level (i.e., the priority value set to 1).

[0137] Otherwise, if the SCI associated with the PSFCH transmission does not indicate that the PSSCH transmitted in the same slot as the SCI is within the reference duration, then the priority value for the PSFCH is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH. Note that the priority value indicated by the SCI format 1-A associated with the PSFCH transmission may be 1; however, it is more likely that the indicated priority level will be greater than 1 (i.e., indicating a lower priority level). Accordingly, in one aspect of the third solution, the Rx UE may override a priority level/value signaled by SCI format 1-A when the SCI indicates that the PSSCH transmitted in the same slot as the SCI is within the reference duration.

[0138] According to embodiments of a fourth solution, for any given PSFCH occasion, a UE sets at most a preconfigurable number pv_{CW} of priority values for a PSFCH equal to 1 according to the above disclosed procedures. Note that it may still happen that multiple PSFCH priority values are 1, e.g., if the priority value indicated by an SCI format 1-A associated with the PSFCH happens to be 1.

[0139] According to one specific implementation, $pv_{CW} = 1$. According to another specific implementation, $pv_{CW} = 1$ per source identifier (Source ID) (e.g., as indicated by the 2nd stage SCI) within the SCI associated with the PSFCH.

[0140] In some embodiments, when multiple candidate PSFCH transmissions qualify for priority value modification, the pv_{CW} number of PSFCHs whose priority value is set to 1 according to the above disclosed procedures is/are determined in accordance with the lowest (i.e., smallest) priority value indicated in the associated SCI formats 1-A for which the disclosed condition evaluates as true.

[0141] For example, if two PSFCHs are determined to be within a reference duration, and $pv_{CW} = 1$, then the priority value for the PSFCH for which the associated SCI indiates the lower priority value is set to 1.

[0142] According to embodiments of a fifth solution, a UE may increase the priority level of a PSFCH transmission carrying HARQ-ACK information based on a cast type (e.g., unicast, groupcast, broadcast) of an associated PSSCH transmission. In certain embodiments, setting “a priority value for the PSFCH is equal to 1” is only applicable if the PSFCH is associated with a unicast cast type of the PSSCH transmission. In one aspect, a Tx UE may assume that the corresponding PSFCH transmission by an Rx UE, i.e., the corresponding PSFCH reception from the Tx UE’s perspective, is associated with an increased priority level (i.e., the priority value set to 1). Otherwise, for other cast types, a priority value for the PSFCH is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH. The cast type may be implicitly tied to the 2nd stage SCI format, or explicitly indicated by the 2nd stage SCI format.

[0143] According to embodiments of a sixth solution, a UE may increase the priority level of a PSFCH transmission carrying HARQ-ACK information based on an acknowledgement type (e.g., ACK or NACK) of the HARQ-ACK information. In some embodiments, setting “a priority value for the PSFCH is equal to 1” is only applicable if the PSFCH carries a positive acknowledgement (i.e., ACK). In one aspect, a Tx UE may assume that the corresponding PSFCH transmission by an Rx UE, i.e., the corresponding PSFCH reception from the Tx UE’s perspective, is associated with an increased priority level (i.e., the priority value set to 1). Otherwise, for other acknowledgement types, a priority value for the PSFCH is equal to the priority value indicated by an SCI format 1-A associated with the PSFCH.

[0144] According to a seventh aspect, instead of setting a priority value for the PSFCH to 1 according to the various aspects, the corresponding priority field value is assumed to be 1 for the purpose of determining the PSFCH priority. This is technically equivalent but may have syntax advantages in view of existing specifications, since these procedures refer to the “corresponding priority field values” rather than the “corresponding priority values.”

[0145] As an example (adapted from the first solution above), for a PSFCH transmission or reception with HARQ-ACK information, if the PSSCH associated with the PSFCH is transmitted within the reference duration, then the UE assumes that priority field value in the corresponding

SCI for the PSFCH is equal to 1 (i.e., the UE ignores the actual value and processes the PSFCH as if the priority value were 1). Otherwise, if the PSSCH associated with the PSFCH is transmitted within the reference duration, then the priority value for the PSFCH is equal to the actual value indicated by an SCI format 1-A associated with the PSFCH.

[0146] According to embodiments of an eighth solution, the Tx UE indicates whether the PSSCH associated with the SCI is within a reference duration (i.e., the feedback is relevant for CW adjustment). This indication signals to the Rx UE that the priority level of a corresponding PSFCH transmission should be increased (i.e., the priority value set to 1) in accordance with the above procedures. In one aspect, the Tx UE may assume that the corresponding PSFCH transmission by the Rx UE, i.e., the corresponding PSFCH reception from the Tx UE's perspective, is associated with an increased priority level (i.e., the priority value set to 1).

[0147] For example, such an indication may be a 1-bit (or larger) field in a 1st stage SCI format (such as SCI format 1-A) or in a 2nd stage SCI format (such as SCI format 2-A, 2-B, 2-C). For example, a field value of '1' may indicate that the PSSCH associated with the SCI is within a reference duration, while a field value of '0' may indicate that the PSSCH associated with the SCI is not within a reference duration. Of course, these values are only examples and in other embodiments different values may be used to indicate whether the PSSCH associated with the SCI is within a reference duration.

[0148] In some embodiments of the eight solution, this indication in SCI is only applicable to the PSSCH transmitted in the same slot as the associated SCI (and not to PSSCHs transmitted in future slots reserved/indicated by the associated SCI).

[0149] Figure 4 illustrates an example of an exemplary SCI format 1-A that may be used for PSFCH priority determination, in accordance with aspects of the present disclosure. The SCI format 1-A is used for the scheduling of PSSCH and 2nd-stage-SCI on PSSCH. As depicted, the following information is transmitted by means of the SCI format 1-A:

[0150] The priority field 402 may comprise 3 bits (e.g., as specified in clause 5.4.3.3 of 3GPP TS 23.287 and clause 5.22.1.3.1 of 3GPP TS 38.321). In various embodiments, a value '000' of the Priority field 402 corresponds to priority value '1', a value '001' of Priority field 402 corresponds to priority value '2', and so on.

[0151] The reference window indicator 404 may comprise 1 bit. This indicator 404 may be used to indicate whether the PSSCH associated with the SCI is within a reference duration.

[0152] The frequency resource assignment field 406 may comprise $\left\lceil \log_2\left(\frac{N_{\mathrm{subChannel}}^{\mathrm{SL}}\left(N_{\mathrm{subChannel}}^{\mathrm{SL}}+1\right)}{2}\right)\right\rceil$ bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 2. Otherwise, the frequency resource assignment field 406 may comprise $\left\lceil \log_2\left(\frac{N_{\mathrm{subChannel}}^{\mathrm{SL}}\left(N_{\mathrm{subChannel}}^{\mathrm{SL}}+1\right)\left(2N_{\mathrm{subChannel}}^{\mathrm{SL}}+1\right)}{6}\right)\right\rceil$ bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 3 (e.g., as defined in clause 8.1.5 of 3GPP TS 38.214).

[0153] The time resource assignment field 408 may comprise 5 bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 2. Otherwise, the time resource assignment field 408 may comprise 9 bits when the value of the higher layer parameter *sl-MaxNumPerReserve* is configured to 3 (e.g., as defined in clause 8.1.5 of 3GPP TS 38.214).

[0154] The resource reservation period field 410 may comprise $\lceil \log_2 N_{\mathrm{rsv\_period}} \rceil$ bits (e.g., as defined in clause 16.4 of 3GPP TS 38.213), where $N_{\mathrm{rsv\_period}}$ is the number of entries in the higher layer parameter *sl-ResourceReservePeriodList*, if higher layer parameter *sl-MultiReserveResource* is configured. Otherwise, the resource reservation period field 410 may comprise 0 bits.

[0155] The demodulation reference signal (DMRS) pattern field 412 may comprise $\lceil \log_2 N_{\mathrm{pattern}} \rceil$ bits (e.g., as defined in clause 8.4.1.1.2 of 3GPP TS 38.211), where N_{pattern} is the number of DMRS patterns configured by higher layer parameter *sl-PSSCH-DMRS-TimePatternList*.

[0156] The 2$^{\mathrm{nd}}$-stage SCI format filed 414 may comprise 2 bits, e.g., as defined in Table 8.3.1.1-1 of 3GPP TS 38.211.

[0157] The Beta_offset indicator 416 may comprise 2 bits, e.g., as provided by higher layer parameter *sl-BetaOffsets2ndSCI* and Table 8.3.1.1-2 of 3GPP TS 38.211.

[0158] The number of DMRS port field 418 may comprise 1 bit, e.g., as defined in Table 8.3.1.1-3 of 3GPP TS 38.211.

[0159] The MCS field 420 may comprise 5 bits, e.g., as defined in clause 8.1.3 of 3GPP TS 38.214.

[0160] The Additional MCS table indicator 422 may comprise 1 bit if one MCS table is configured by higher layer parameter *sl-Additional-MCS-Table*; 2 bits if two MCS tables are configured by higher layer parameter *sl-Additional-MCS-Table*; and 0 bit otherwise.

[0161] The PSFCH overhead indicator 424 may comprise 1 bit (e.g., as defined clause 8.1.3.2 of 3GPP TS 38.214) if higher layer parameter *sl-PSFCH-Period* = 2 or 4. Otherwise, the PSFCH overhead indicator 424 may comprise 0 bits.

[0162] The reserved field 426 may comprise a number of bits as determined by the following: $N_{reserved}$ bits as configured by higher layer parameter *sl-NumReservedBits,* with value set to zero, if higher layer parameter *sl-IndicationUE-B* is not configured, or if higher layer parameter *sl-IndicationUE-B* is configured to 'disabled'; $(N_{\text{reserved}} - 1)$ bits otherwise, with value set to zero.

[0163] The conflict information receiver flag 428 may comprise 0 or 1 bits. In some embodiments, the flag 428 comprises 1 bit if higher layer parameter *sl-IndicationUE-B* is configured to 'enabled', where the bit value of 0 indicates that the UE cannot be a UE to receive conflict information and the bit value of 1 indicates that the UE can be a UE to receive conflict information (e.g., as defined in clause 16.3.0 of 3GPP TS 38.213). Otherwise, the flag 428 may comprise 0 bits.

[0164] Figure 5 illustrates an example of a UE 500 in accordance with aspects of the present disclosure. The UE 500 may include a processor 502, a memory 504, a controller 506, and a transceiver 508. The processor 502, the memory 504, the controller 506, or the transceiver 508, 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.

[0165] The processor 502, the memory 504, the controller 506, or the transceiver 508, 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.

[0166] The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a central processing unit (CPU), an ASIC, a field programable gate array (FPGA), or any combination thereof). In some implementations, the processor 502 may be configured to operate the memory 504. In some other implementations, the memory 504 may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in the memory 504 to cause the UE 500 to perform various functions of the present disclosure.

[0167] The memory 504 may include volatile or non-volatile memory. The memory 504 may store computer-readable, computer-executable code including instructions when executed by the processor 502 cause the UE 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 504 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.

[0168] In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the UE 500 to perform one or more of the Rx UE functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). For example, the processor 502 may support wireless communication at the UE 500 in accordance with examples as disclosed herein.

[0169] The UE 500 may be configured to support a means for generating a first set of PSFCH transmissions in priority order based at least in part on priority values associated with the PSFCH transmissions, the first set of PSFCH transmissions including a respective PSFCH transmission carrying HARQ-ACK information.

[0170] The UE 500 may be configured to support a means for increasing a priority of the respective PSFCH transmission based at least in part on: i) a transmission time of a PSSCH transmission corresponding to the HARQ-ACK information, ii) an indication in SCI associated with the respective PSFCH transmission, iii) a cast type of the PSSCH transmission, and/or iv) an acknowledgement type of the HARQ-ACK information.

[0171] The UE 500 may be configured to or operable to support a means for transmitting a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based at least in part on modified priority values associated with the PSFCH transmissions, where the second set of PSFCH transmissions includes a portion of the first set of PSFCH transmissions.

[0172] In some embodiments, to increase the priority of the respective PSFCH transmission, the UE 500 may be configured to override an indicated priority value configured by the SCI associated with the respective PSFCH transmission. In some embodiments, to increase the priority of the respective PSFCH transmission, the UE 500 may be configured to set the respective priority value associated with the respective PSFCH transmission to a lowest (i.e., smallest) priority value.

[0173] In some embodiments, the UE 500 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the PSSCH transmission being transmitted within a reference duration corresponding to an end of a first slot of a UE-initiated channel occupancy including a transmission of a respective PSSCH with HARQ-ACK enabled. In some embodiments, the UE 500 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the PSSCH transmission being transmitted in a same slot as the SCI associated with the respective PSFCH transmission.

[0174] In some embodiments, the UE 500 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on an explicit indication in the SCI associated with the respective PSFCH transmission. In certain embodiments, the UE 500 is further configured to increase the priority of the respective PSFCH transmission based at least in part on the PSSCH transmission being transmitted in a same slot as the SCI associated with the respective PSFCH transmission.

[0175] In some embodiments, the UE 500 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the cast type of the PSSCH transmission being a unicast cast type. In some embodiments, the UE 500 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the acknowledgement type being a positive acknowledgment.

[0176] In some embodiments, the UE 500 is configured to increase the priority of up to a preconfigured number of PSFCH transmissions per PSFCH occasion. In certain embodiments, the UE 500 is configured to receive, from a radio access network, a configuration indicating the preconfigured number of PSFCH transmissions.

[0177] In certain embodiments, the preconfigured number of PSFCH transmissions is per source identifier within SCI. In certain embodiments, the first set of PSFCH transmission includes multiple PSFCH transmissions carrying HARQ-ACK information, where the respective PSFCH transmission has a lowest (i.e., smallest) indicated priority value configured by SCI among the multiple PSFCH transmissions carrying HARQ-ACK information.

[0178] In some embodiments, a total transmit power corresponding to the second set of PSFCH transmissions satisfies a configured maximum output power. In some embodiments, a total number of PSFCH transmissions corresponding to the second set of PSFCH transmissions satisfies a configured maximum number.

[0179] In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to cause the UE 500 to perform one or more of the Tx UE functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504). For example, the processor 502 may support wireless communication at the UE 500 in accordance with examples as disclosed herein.

[0180] The UE 500 may be configured to or operable to support a means for transmitting a plurality of PSSCH transmissions to a receiving device (e.g., an Rx UE). The UE 500 may be configured to or operable to support a means for transmitting SCI associated with the plurality of PSSCH transmissions, where the SCI includes an indication that a respective PSSCH transmission is within a reference duration.

[0181] The UE 500 may be configured to or operable to support a means for receiving, e.g., from the receiving device and over an unlicensed carrier, a set of PSFCH transmissions including a respective PSFCH transmission carrying HARQ-ACK information corresponding to the respective PSSCH transmission.

[0182] In some embodiments, the indication is applicable based on the respective PSSCH transmission being transmitted in the same slot as the SCI. In some embodiments, the reference duration corresponds to the end of a first slot of a UE-initiated channel occupancy including a particular PSSCH transmission with HARQ-ACK enabled.

[0183] In some embodiments, the indication indicates an increased priority of the respective PSFCH transmission based on: i) a cast type of the respective PSSCH transmission, and/or ii) an acknowledgement type of the HARQ-ACK information.

[0184] In certain embodiments, the increased priority of the respective PSFCH transmission corresponds to a lowest (i.e., smallest) priority value. In certain embodiments, the increased priority is based on the cast type being a unicast cast type. In certain embodiments, the increased priority is based on the acknowledgement type being a positive acknowledgment.

[0185] The controller 506 may manage input and output signals for the UE 500. The controller 506 may also manage peripherals not integrated into the UE 500. In some implementations, the controller 506 may utilize an operating system (OS) such as iOS®, ANDROID®, WINDOWS®, or other operating systems (OSes). In some implementations, the controller 506 may be implemented as part of the processor 502.

[0186] In some implementations, the UE 500 may include at least one transceiver 508. In some other implementations, the UE 500 may have more than one transceiver 508. The transceiver 508 may represent a wireless transceiver. The transceiver 508 may include one or more receiver chains 510, one or more transmitter chains 512, or a combination thereof.

[0187] A receiver chain 510 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 510 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 510 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 510 may include at least one demodulator configured to demodulate the receiving signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 510 may include at least one decoder for decoding and processing the demodulated signal to receive the transmitted data.

[0188] A transmitter chain 512 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 512 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 512 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 512 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0189] Figure 6 illustrates an example of a processor 600 in accordance with aspects of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. 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).

[0190] The processor 600 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 600) 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).

[0191] The controller 602 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 600 to cause the processor 600 to support various operations in accordance with examples as described herein. For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0192] The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 600.

[0193] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[0194] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 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 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example, the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 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.

[0195] The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 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 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

[0196] The processor 600 may support wireless communication in accordance with examples as disclosed herein. For example, the processor 600 may perform one or more of the UE functions described herein. The processor 600 may be configured to or operable to support a means for generating a first set of PSFCH transmissions in priority order based at least in part on priority values associated with the PSFCH transmissions, the first set of PSFCH transmissions including a respective PSFCH transmission carrying HARQ-ACK information.

[0197] The processor 600 may be configured to or operable to support a means for increasing a priority of the respective PSFCH transmission based at least in part on: i) a transmission time of a PSSCH transmission corresponding to the HARQ-ACK information, ii) an indication in SCI associated with the respective PSFCH transmission, iii) a cast type of the PSSCH transmission, and/or iv) an acknowledgement type of the HARQ-ACK information.

[0198] The processor 600 may be configured to or operable to support a means for transmitting a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based at least in part on modified priority values associated with the PSFCH transmissions, where the second set of PSFCH transmissions includes a portion of the first set of PSFCH transmissions.

[0199] In some embodiments, to increase the priority of the respective PSFCH transmission, the processor 600 may be configured to override an indicated priority value configured by the SCI associated with the respective PSFCH transmission. In some embodiments, to increase the priority of the respective PSFCH transmission, the processor 600 may be configured to set the respective priority value associated with the respective PSFCH transmission to a lowest (i.e., smallest) priority value.

[0200] In some embodiments, the processor 600 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the PSSCH transmission being transmitted within a reference duration corresponding to an end of a first slot of a UE-initiated channel occupancy including a transmission of a respective PSSCH with HARQ-ACK enabled. In some embodiments, the processor 600 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the PSSCH transmission being transmitted in a same slot as the SCI associated with the respective PSFCH transmission.

[0201] In some embodiments, the processor 600 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on an explicit indication in the SCI associated with the respective PSFCH transmission. In certain embodiments, the processor 600 is further configured to increase the priority of the respective PSFCH transmission based at least in part on the PSSCH transmission being transmitted in a same slot as the SCI associated with the respective PSFCH transmission.

[0202] In some embodiments, the processor 600 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the cast type of the PSSCH transmission being a unicast cast type. In some embodiments, the processor 600 is configured to increase the priority of the respective PSFCH transmission to a highest priority based at least in part on the acknowledgement type being a positive acknowledgment.

[0203] In some embodiments, the processor 600 is configured to increase the priority of up to a preconfigured number of PSFCH transmissions per PSFCH occasion. In certain embodiments, the processor 600 is configured to receive, from a radio access network, a configuration indicating the preconfigured number of PSFCH transmissions.

[0204] In certain embodiments, the preconfigured number of PSFCH transmissions is per source identifier within SCI. In certain embodiments, the first set of PSFCH transmission includes multiple PSFCH transmissions carrying HARQ-ACK information, where the respective PSFCH transmission has a lowest (i.e., smallest) indicated priority value configured by SCI among the multiple PSFCH transmissions carrying HARQ-ACK information.

[0205] In some embodiments, a total transmit power corresponding to the second set of PSFCH transmissions satisfies a configured maximum output power. In some embodiments, a total number of PSFCH transmissions corresponding to the second set of PSFCH transmissions satisfies a configured maximum number.

[0206] In further embodiments, the processor 600 may perform one or more of the Tx UE functions described herein.

[0207] The processor 600 may be configured to or operable to support a means for transmitting a plurality of PSSCH transmissions to a receiving device (e.g., an Rx UE). The processor 600 may be configured to or operable to support a means for transmitting SCI associated with the plurality of PSSCH transmissions, where the SCI includes an indication that a respective PSSCH transmission is within a reference duration.

[0208] The processor 600 may be configured to or operable to support a means for receiving, e.g., from the receiving device and over an unlicensed carrier, a set of PSFCH transmissions including a respective PSFCH transmission carrying HARQ-ACK information corresponding to the respective PSSCH transmission.

[0209] In some embodiments, the indication is applicable based on the respective PSSCH transmission being transmitted in the same slot as the SCI. In some embodiments, the reference duration corresponds to the end of a first slot of a UE-initiated channel occupancy including a particular PSSCH transmission with HARQ-ACK enabled.

[0210] In some embodiments, the indication indicates an increased priority of the respective PSFCH transmission based on: i) a cast type of the respective PSSCH transmission, and/or ii) an acknowledgement type of the HARQ-ACK information.

[0211] In certain embodiments, the increased priority of the respective PSFCH transmission corresponds to a lowest (i.e., smallest) priority value. In certain embodiments, the increased priority is based on the cast type being a unicast cast type. In certain embodiments, the increased priority is based on the acknowledgement type being a positive acknowledgment.

[0212] Figure 7 illustrates an example of a NE 700 in accordance with aspects of the present disclosure. The NE 700 may include a processor 702, a memory 704, a controller 706, and a transceiver 708. The processor 702, the memory 704, the controller 706, or the transceiver 708, 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.

[0213] The processor 702, the memory 704, the controller 706, or the transceiver 708, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a DSP, an 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.

[0214] The processor 702 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 702 may be configured to operate the memory 704. In some other implementations, the memory 704 may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in the memory 704 to cause the NE 700 to perform various functions of the present disclosure.

[0215] The memory 704 may include volatile or non-volatile memory. The memory 704 may store computer-readable, computer-executable code including instructions when executed by the processor 702 cause the NE 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 704 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.

[0216] In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the NE 700 to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). For example, the processor 702 may support wireless communication at the NE 700 in accordance with examples as disclosed herein.

[0217] In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to cause the NE 700 to perform one or more of the NE functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704). For example, the processor 702 may support wireless communication at the NE 700 in accordance with examples as disclosed herein.

[0218] The controller 706 may manage input and output signals for the NE 700. The controller 706 may also manage peripherals not integrated into the NE 700. In some implementations, the controller 706 may utilize an OS such as iOS®, ANDROID®, WINDOWS®, or other OSes. In some implementations, the controller 706 may be implemented as part of the processor 702.

[0219] In some implementations, the NE 700 may include at least one transceiver 708. In some other implementations, the NE 700 may have more than one transceiver 708. The transceiver 708 may represent a wireless transceiver. The transceiver 708 may include one or more receiver chains 710, one or more transmitter chains 712, or a combination thereof.

[0220] A receiver chain 710 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 710 may include one or more antennas for receiving the signal over the air or wireless medium. The receiver chain 710 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 710 may include at least one demodulator configured to demodulate the receiving signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 710 may include at least one decoder for decoding and processing the demodulated signal to receive the transmitted data.

[0221] A transmitter chain 712 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 712 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 AM, FM, or digital modulation schemes like PSK or QAM. The transmitter chain 712 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 712 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0222] Figure 8 illustrates a flowchart of a method 800 in accordance with aspects of the present disclosure. The operations of the method 800 may be implemented by a Rx UE as described herein. In some implementations, the Rx UE may execute a set of instructions to control the function elements of the Rx UE to perform the described functions.

[0223] At Step 802, the method 800 may include generating a first set of PSFCH transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set of PSFCH transmissions including a respective PSFCH transmission carrying HARQ-ACK information. The operations of Step 802 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 802 may be performed by a UE as described with reference to Figure 5.

[0224] At Step 804, the method 800 may include increasing a priority of the respective PSFCH transmission based on: i) a transmission time of a PSSCH transmission corresponding to the HARQ-ACK information, ii) an indication in SCI associated with the respective PSFCH transmission, iii) a cast type of the PSSCH transmission, and/or iv) an acknowledgement type of the HARQ-ACK information. The operations of Step 804 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 804 may be performed by a UE as described with reference to Figure 5.

[0225] At Step 806, the method 800 may include transmitting a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, where the second set of PSFCH transmissions includes a portion of the first set of PSFCH transmissions. The operations of Step 806 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 806 may be performed by a UE as described with reference to Figure 5.

[0226] It should be noted that the method 800 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0227] Figure 9 illustrates a flowchart of a method 900 in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a Tx UE as described herein. In some implementations, the Tx UE may execute a set of instructions to control the function elements of the Tx UE to perform the described functions.

[0228] At Step 902, the method 900 may include transmitting a plurality of PSSCH transmissions to a receiving device. The operations of Step 902 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 902 may be performed by a UE as described with reference to Figure 5.

[0229] At Step 904, the method 900 may include transmitting SCI associated with the plurality of PSSCH transmissions, where the SCI includes an indication that a respective PSSCH transmission is within a reference duration. The operations of Step 904 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 904 may be performed by a UE as described with reference to Figure 5.

[0230] At Step 906, the method 900 may include receiving, from the receiving device and over an unlicensed carrier, a set of PSFCH transmissions comprising a respective PSFCH transmission carrying HARQ-ACK information corresponding to the respective PSSCH transmission. The operations of Step 906 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of Step 906 may be performed by a UE as described with reference to Figure 5.

[0231] It should be noted that the method 900 described herein describes one possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0232] Embodiments may be practiced in other specific forms. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

1. A User Equipment (UE) for wireless communication, comprising:
   at least one memory; and
   at least one processor coupled with the at least one memory and configured to cause the UE to:
      generate a first set of physical sidelink feedback channel (PSFCH) transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set of PSFCH transmissions comprising a respective PSFCH transmission carrying Hybrid Automatic Repeat Request Acknowledgement (HARQ-ACK) information;
      increase a priority of the respective PSFCH transmission based on:
         a transmission time of a physical sidelink shared channel (PSSCH) transmission corresponding to the HARQ-ACK information,
         an indication in sidelink control information (SCI) associated with the respective PSFCH transmission,
         a cast type of the PSSCH transmission,
         an acknowledgement type of the HARQ-ACK information,
         or any combination thereof; and
      transmit a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, wherein the second set of PSFCH transmissions comprises a portion of the first set of PSFCH transmissions.

2. The UE of claim 1, wherein to increase the priority of the respective PSFCH transmission, the at least one processor is configured to cause the UE to override an indicated priority value configured by the SCI associated with the respective PSFCH transmission.

3. The UE of claim 1, wherein the at least one processor is configured to cause the UE to set a respective priority value associated with the respective PSFCH transmission to a lowest priority value.

4. The UE of claim 1, wherein the at least one processor is configured to cause the UE to increase the priority of the respective PSFCH transmission to a highest priority based on the PSSCH transmission being transmitted within a reference duration corresponding to an end of a first slot of a UE-initiated channel occupancy including a transmission of a respective PSSCH with HARQ-ACK enabled.

5. The UE of claim 1, wherein the at least one processor is configured to cause the UE to increase the priority of the respective PSFCH transmission to a highest priority based on the PSSCH transmission being transmitted in a same slot of as the SCI associated with the respective PSFCH transmission.

6. The UE of claim 1, wherein the at least one processor is configured to cause the UE to increase the priority of the respective PSFCH transmission to a highest priority based on an explicit indication in the SCI associated with the respective PSFCH transmission.

7. The UE of claim 1, wherein the at least one processor is configured to cause the UE to increase the priority of the respective PSFCH transmission to a highest priority based on the cast type of the PSSCH transmission being a unicast cast type or the acknowledgement type being a positive acknowledgment.

8. The UE of claim 1, wherein the at least one processor is configured to cause the UE to increase the priority of up to a preconfigured number of PSFCH transmissions per PSFCH occasion.

9. The UE of claim 8, wherein the preconfigured number of PSFCH transmissions is per source identifier within SCI.

10. The UE of claim 8, wherein the at least one processor is configured to cause the UE to receive, from a radio access network, a configuration indicating the preconfigured number of PSFCH transmissions.

11. The UE of claim 8, wherein the first set of PSFCH transmissions comprises multiple PSFCH transmissions carrying HARQ-ACK information, wherein the respective PSFCH transmission has a lowest indicated priority value configured by SCI among the multiple PSFCH transmissions carrying HARQ-ACK information.

12. The UE of claim 1, wherein a total transmit power corresponding to the second set of PSFCH transmissions satisfies a configured maximum output power, and wherein a total number of PSFCH transmissions corresponding to the second set of PSFCH transmissions satisfies a configured maximum number.

13. 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 first set of physical sidelink feedback channel (PSFCH) transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set of PSFCH transmissions comprising a respective PSFCH transmission carrying Hybrid Automatic Repeat Request Acknowledgement (HARQ-ACK) information;
increase a priority of the respective PSFCH transmission based on:
a transmission time of a physical sidelink shared channel (PSSCH) transmission corresponding to the HARQ-ACK information,
an indication in sidelink control information (SCI) associated with the respective PSFCH transmission,
a cast type of the PSSCH transmission,
an acknowledgement type of the HARQ-ACK information,
or any combination thereof; and
transmit a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, wherein the second set of PSFCH transmissions comprises a portion of the first set of PSFCH transmissions.

14. A User Equipment (UE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the UE to:
transmit a plurality of physical sidelink shared channel (PSSCH) transmissions to a receiving device;

transmit sidelink control information (SCI) associated with the plurality of PSSCH transmissions, wherein the SCI comprises an indication that a respective PSSCH transmission is within a reference duration; and

receive, from the receiving device and over an unlicensed carrier, a set of physical sidelink feedback channel (PSFCH) transmissions comprising a respective PSFCH transmission carrying Hybrid Automatic Repeat Request Acknowledgement (HARQ-ACK) information corresponding to the respective PSSCH transmission.

15. The UE of claim 14, wherein the indication is applicable based on the respective PSSCH transmission being transmitted in a same slot as the SCI.

16. The UE of claim 14, wherein the indication indicates an increased priority of the respective PSFCH transmission based on:

a cast type of the respective PSSCH transmission,

an acknowledgement type of the HARQ-ACK information,

or any combination thereof.

17. The UE of claim 16, wherein the increased priority of the respective PSFCH transmission corresponds to a lowest priority value.

18. The UE of claim 16, wherein the increased priority is based on the cast type being a unicast cast type or the acknowledgement type being a positive acknowledgment.

19. The UE of claim 14, wherein the reference duration corresponds to an end of a first slot of a UE-initiated channel occupancy including a particular PSSCH transmission with HARQ-ACK enabled.

20. A processor for wireless communication, comprising:

at least one controller coupled with at least one memory and configured to cause the processor to:

transmit a plurality of physical sidelink shared channel (PSSCH) transmissions to a receiving device;

transmit sidelink control information (SCI) associated with the plurality of PSSCH transmissions, wherein the SCI comprises an indication that a respective PSSCH transmission is within a reference duration; and receive, from the receiving device and over an unlicensed carrier, a set of physical sidelink feedback channel (PSFCH) transmissions comprising a respective PSFCH transmission carrying Hybrid Automatic Repeat Request Acknowledgement (HARQ-ACK) information corresponding to the respective PSSCH transmission.

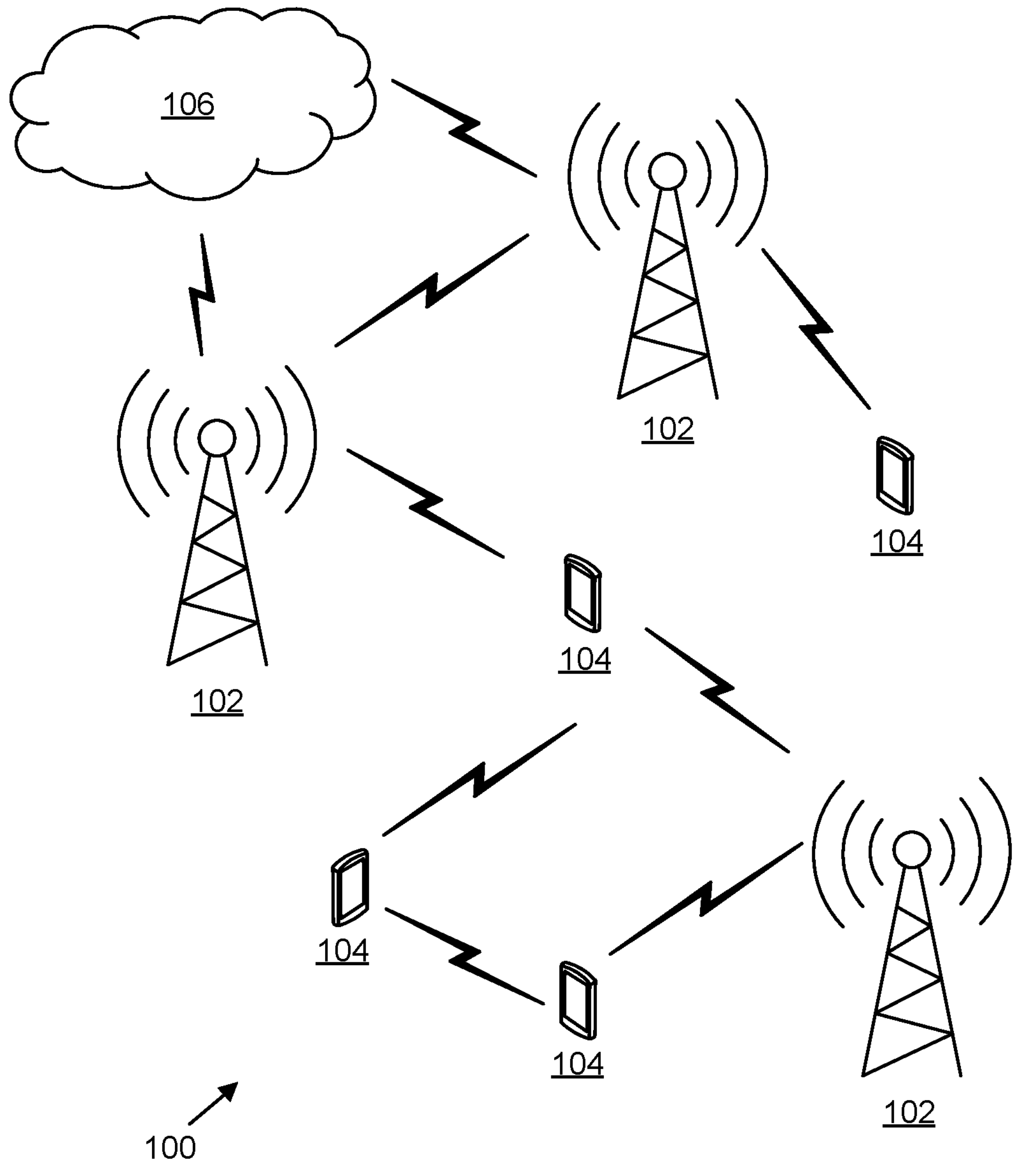
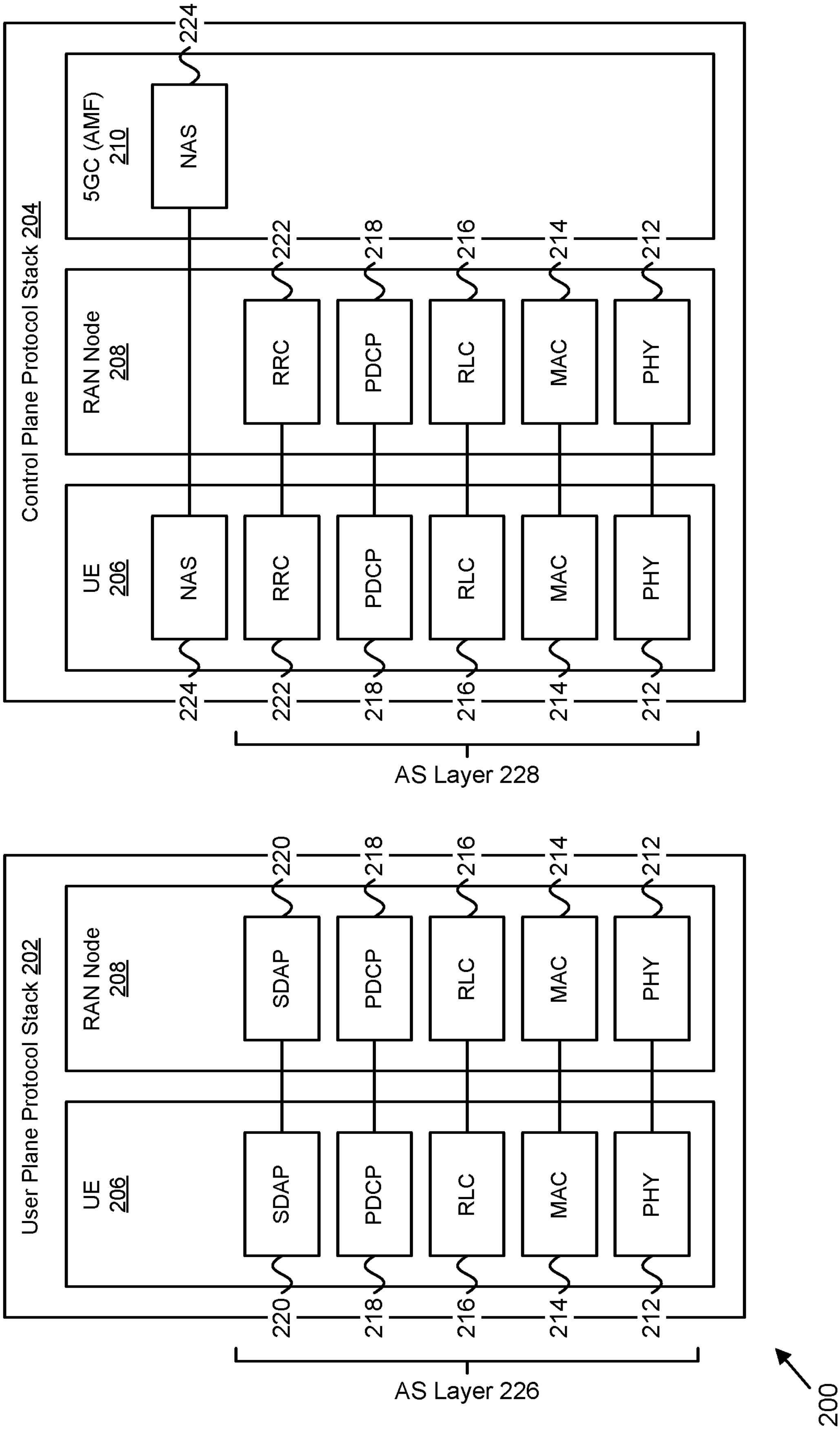


FIG. 1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UE 206
RAN Node 208
5GC (AMF) 210
NAS
RRC
PDCP
RLC
MAC
PHY
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222
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216
214
212
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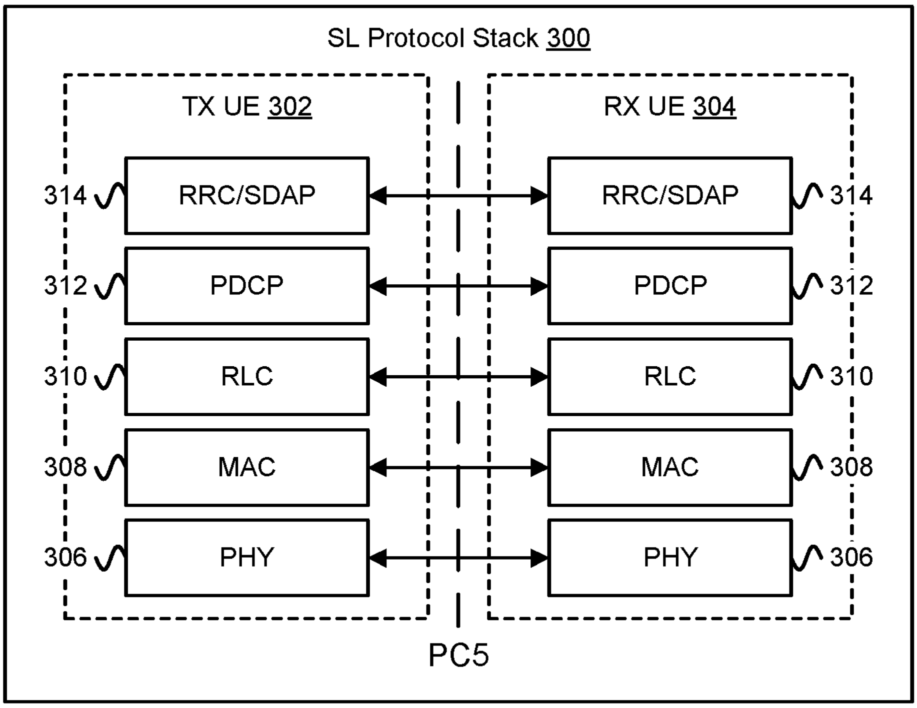
SDAP
220
AS Layer 226
200

FIG. 2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TX UE 302
RX UE 304
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PDCP
RLC
MAC
PHY
314
312
310
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306
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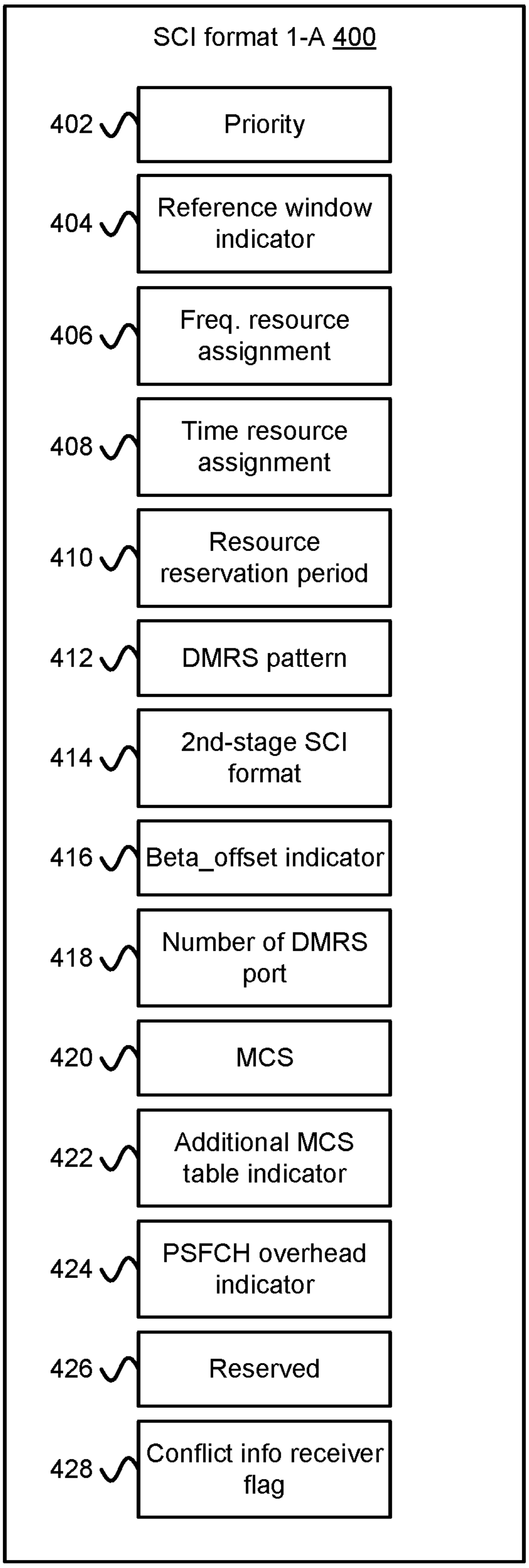
RLC
MAC
PHY
314
312
310
308
306
PC5

FIG. 3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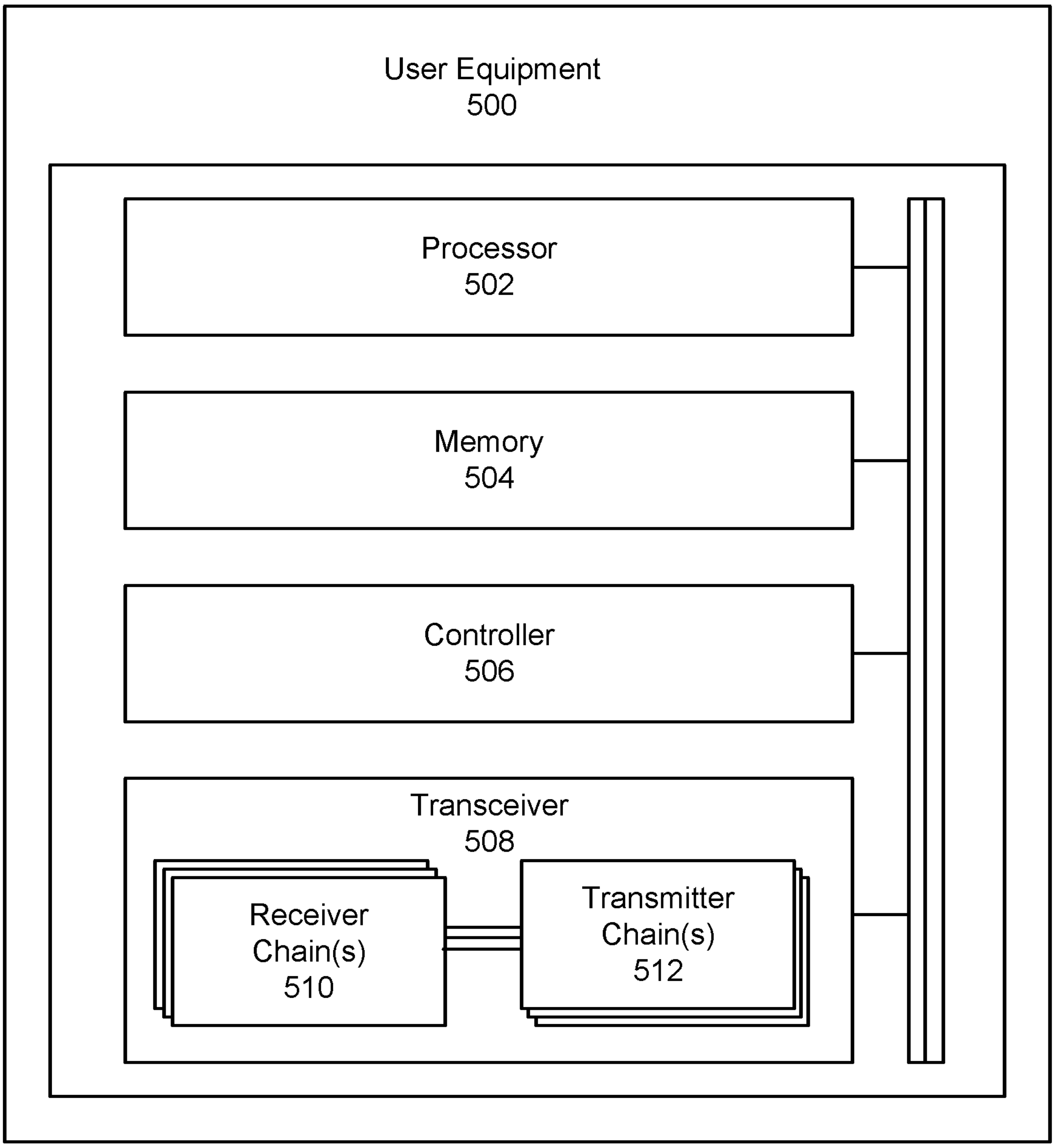
402
Priority
404
Reference window indicator
406
Freq. resource assignment
408
Time resource assignment
410
Resource reservation period
412
DMRS pattern
414
2nd-stage SCI format
416
Beta_offset indicator
418
Number of DMRS port
420
MCS
422
Additional MCS table indicator
424
PSFCH overhead indicator
426
Reserved
428
Conflict info receiver flag

FIG. 4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Processor
502
Memory
504
Controller
506
Transceiver
508
Receiver
Chain(s)
510
Transmitter
Chain(s)
512

FIG. 5

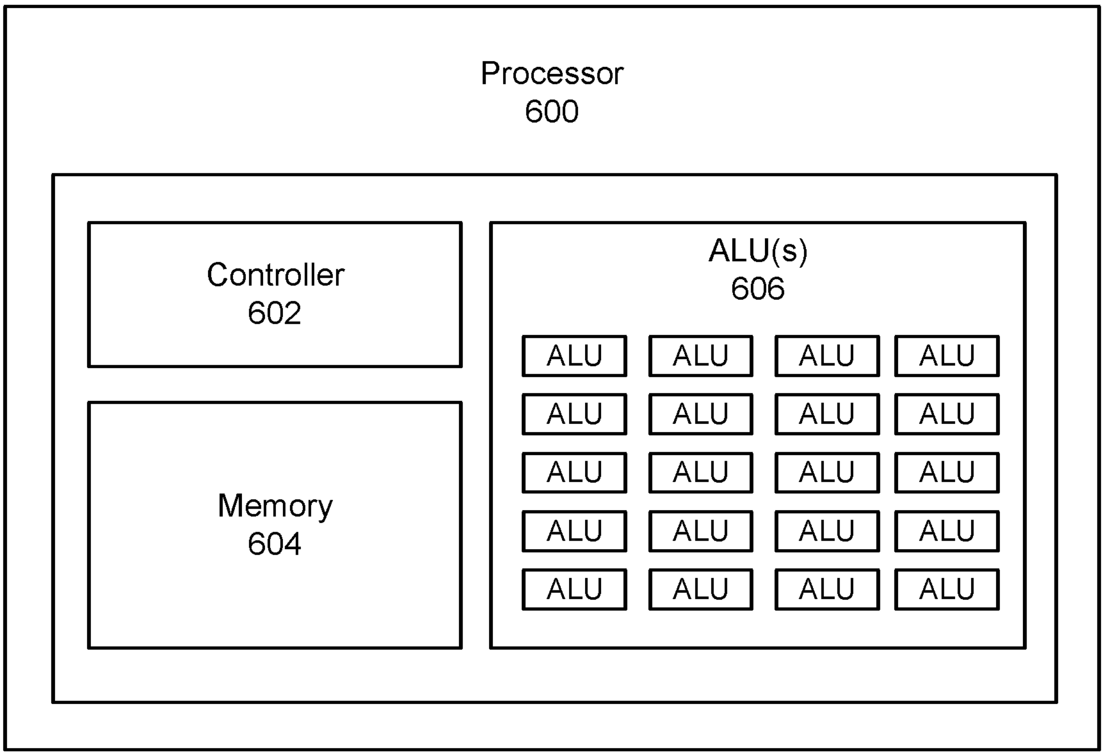
Processor
600
Controller
602
Memory
604
ALU(s)
606
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU
ALU

FIG. 6

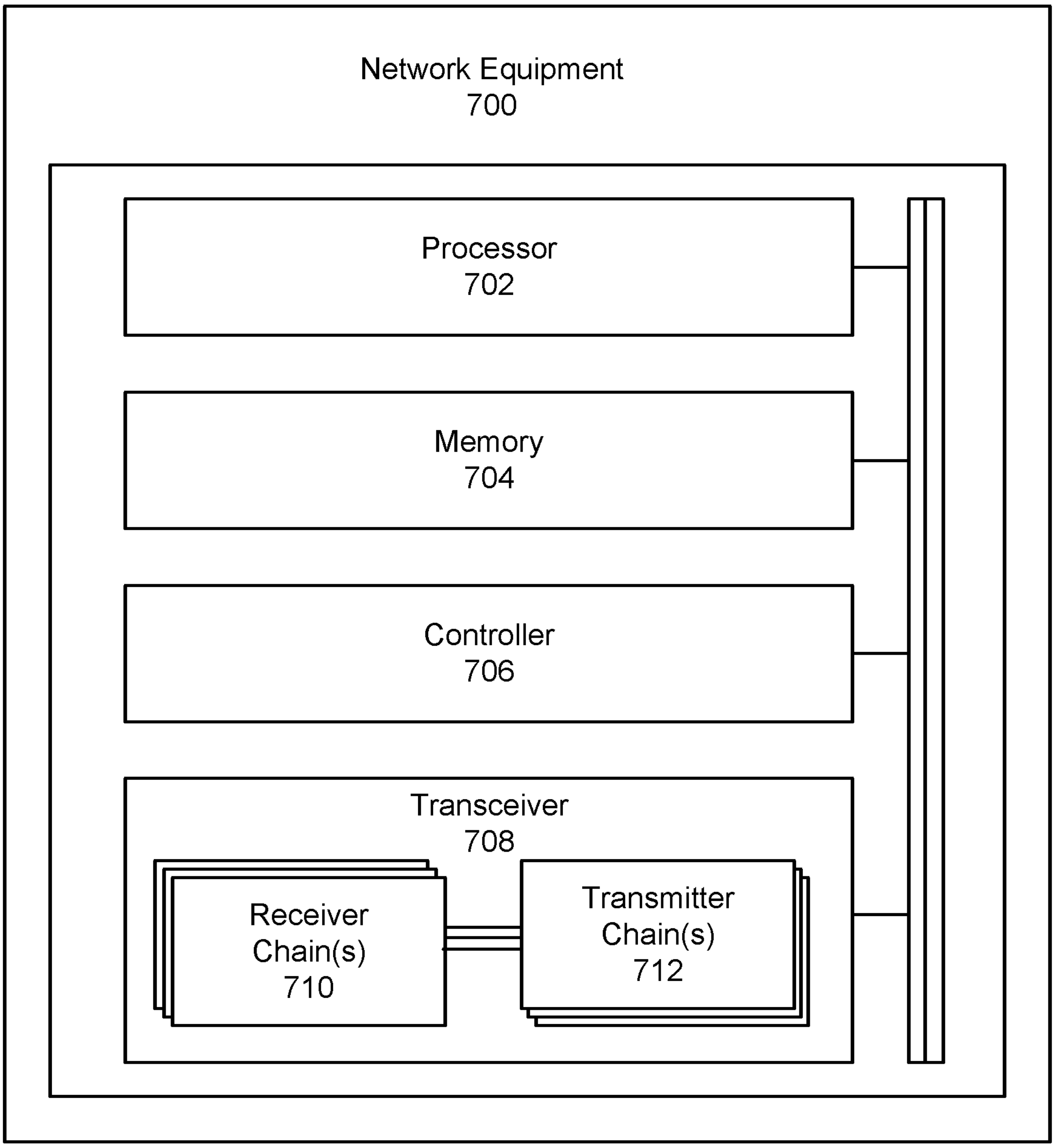
Network Equipment
700
Processor
702
Memory
704
Controller
706
Transceiver
708
Receiver
Chain(s)
710
Transmitter
Chain(s)
712

FIG. 7

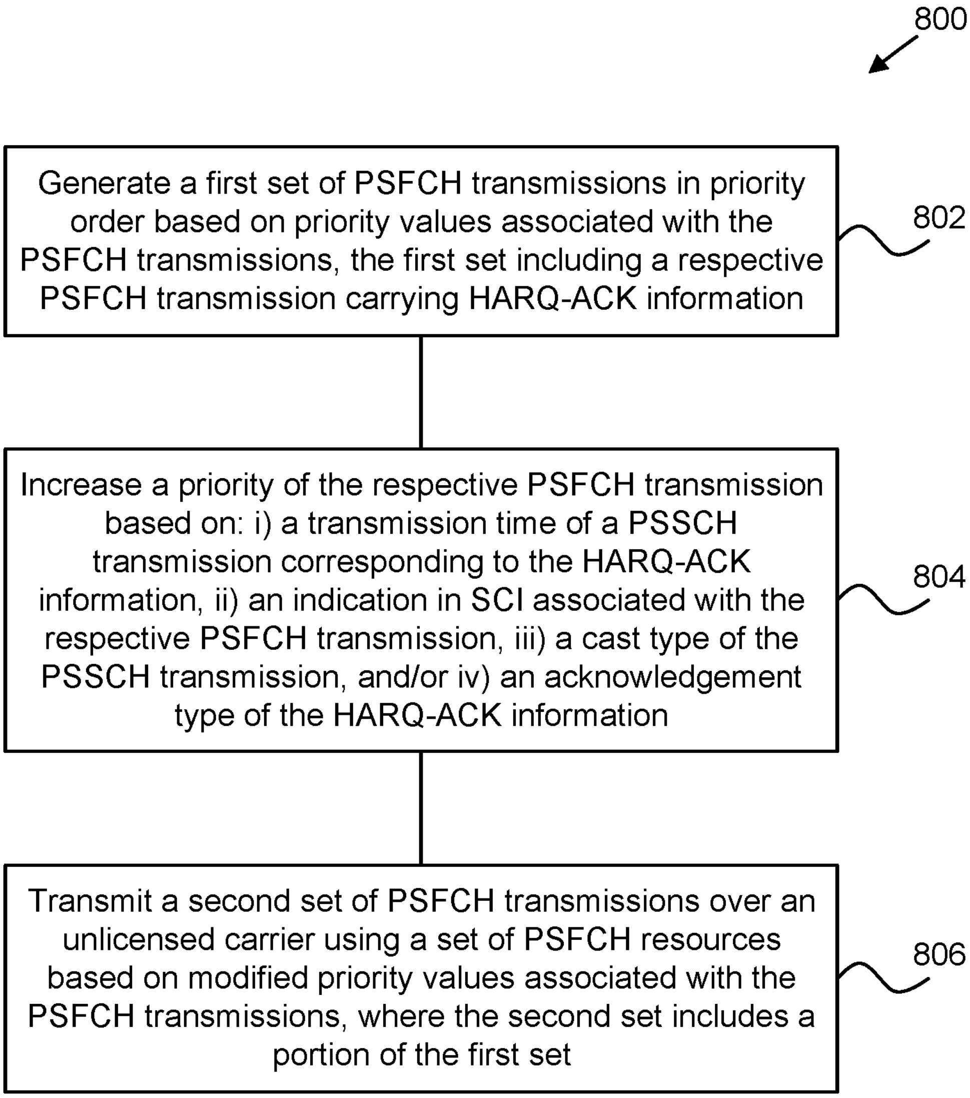
800
Generate a first set of PSFCH transmissions in priority order based on priority values associated with the PSFCH transmissions, the first set including a respective PSFCH transmission carrying HARQ-ACK information
802
Increase a priority of the respective PSFCH transmission based on: i) a transmission time of a PSSCH transmission corresponding to the HARQ-ACK information, ii) an indication in SCI associated with the respective PSFCH transmission, iii) a cast type of the PSSCH transmission, and/or iv) an acknowledgement type of the HARQ-ACK information
804
Transmit a second set of PSFCH transmissions over an unlicensed carrier using a set of PSFCH resources based on modified priority values associated with the PSFCH transmissions, where the second set includes a portion of the first set
806

FIG. 8

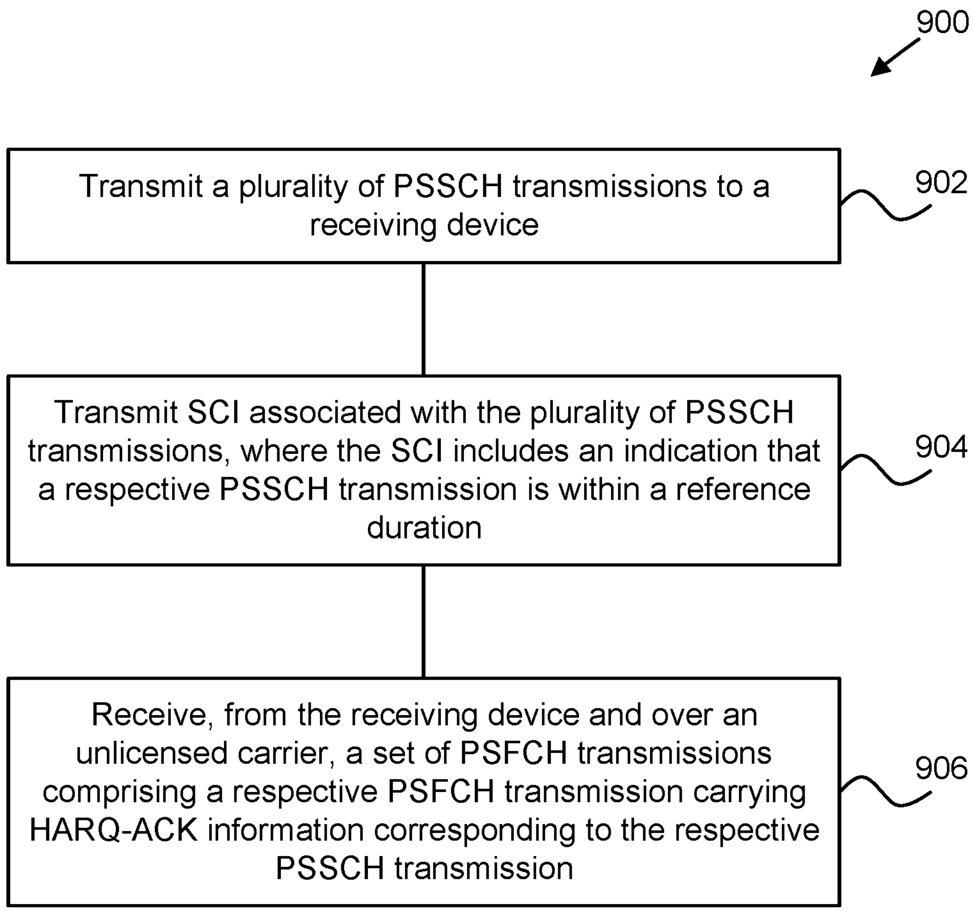
900
Transmit a plurality of PSSCH transmissions to a receiving device
902
Transmit SCI associated with the plurality of PSSCH transmissions, where the SCI includes an indication that a respective PSSCH transmission is within a reference duration
904
Receive, from the receiving device and over an unlicensed carrier, a set of PSFCH transmissions comprising a respective PSFCH transmission carrying HARQ-ACK information corresponding to the respective PSSCH transmission
906

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/053261

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/1829
ADD.

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)
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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MINSEOK NOH ET AL: "Discussion on channel access mechanism for SL-U", 3GPP DRAFT; R1-2301734; TYPE DISCUSSION; NR_SL_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 18 February 2023 (2023-02-18), XP052248864, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301734.zip R1-2301734_channel_access_SL_final.docx [retrieved on 2023-02-18] pages 7,12	1-20

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[x] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 June 2024	04/07/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Besse, Jean

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/053261

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.

A	DONGHYUN PARK ET AL: "Channel Access Mechanism for SL-U", 3GPP DRAFT; R1-2301627; TYPE DISCUSSION; NR_SL_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052248757, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2301627.zip R1-2301627_Channel_Access.docx [retrieved on 2023-02-17] page 3	1,13,14, 20

A	TORSTEN WILDSCHEK ET AL: "On Channel Access Mechanism for SL-U", 3GPP DRAFT; R1-2300036; TYPE DISCUSSION; NR_SL_ENH2-CORE, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. 3GPP RAN 1, no. Athens, GR; 20230227 - 20230303 17 February 2023 (2023-02-17), XP052247190, Retrieved from the Internet: URL:https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_112/Docs/R1-2300036.zip R1-2300036-SL-U-ChannelAccessMechanism.docx [retrieved on 2023-02-17] page 9	1,13,14, 20
