(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
16 November 2023 (16.11.2023)

WIPO | PCT

(10) **International Publication Number**
WO 2023/217659 A1

(51) **International Patent Classification:**
H04W 72/40 (2023.01) *H04W 72/02* (2009.01)
H04L 5/00 (2006.01) *H04W 72/23* (2023.01)

(21) **International Application Number:**
PCT/EP2023/061988

(22) **International Filing Date:**
05 May 2023 (05.05.2023)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
63/339,630 09 May 2022 (09.05.2022) US

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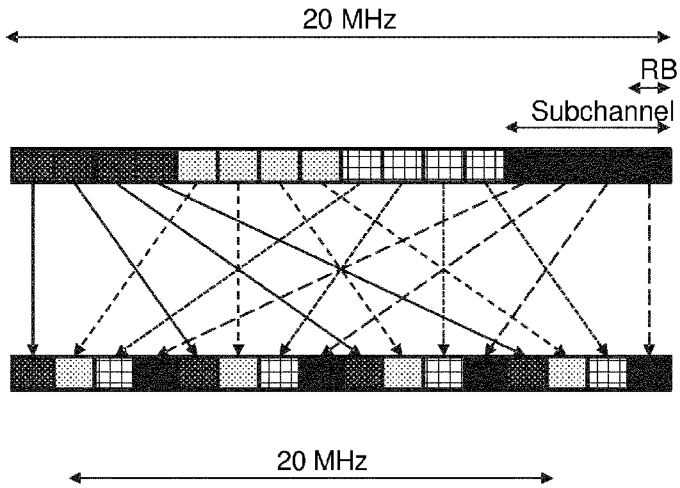
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) **Title:** INTERLACED SIDELINK COMMUNICATION

FIG. 12



(57) **Abstract:** A user equipment, UE, determines a configuration for one or more sidelink, SL, resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non- overlapping sub-channels. Each sub-channel comprises a plurality of resource blocks, RBs, that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

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Published:

— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

INTERLACED SIDELINK COMMUNICATION

TECHNICAL FIELD

Embodiments of the present disclosure generally relate to wireless communication networks, and particularly relates to improving device-to-device (D2D) communication between user equipment (UEs) in channels where UE transmissions are interlaced in frequency, e.g., to meet regulations for channels in unlicensed spectrum.

BACKGROUND

Currently the fifth generation ("5G") of cellular systems, also referred to as New Radio (NR), is being standardized within the Third-Generation Partnership Project (3GPP). NR is developed for maximum flexibility to support multiple and substantially different use cases. These include enhanced mobile broadband (eMBB), machine type communications (MTC), ultra-reliable low latency communications (URLLC), side-link device-to-device (D2D), and several other use cases. NR was initially specified in 3GPP Release 15 (Rel-15) and continues to evolve through subsequent releases, such as Rel-16 and Rel-17.

5G/NR technology shares many similarities with fourth-generation Long-Term Evolution (LTE). For example, NR uses CP-OFDM (Cyclic Prefix Orthogonal Frequency Division Multiplexing) in the downlink (DL) from network to user equipment (UE), and both CP-OFDM and DFT-spread OFDM (DFT-S-OFDM) in the uplink (UL) from UE to network. As another example, NR DL and UL time-domain physical resources are organized into equal-sized 1-ms subframes. A subframe is divided into multiple slots of equal duration, with each slot including multiple OFDM-based symbols. Time-frequency resources can be configured much more flexibly for an NR cell than for an LTE cell. For example, rather than a fixed 15-kHz OFDM sub-carrier spacing (SCS) as in LTE, NR SCS can range from 15 to 240 kHz, with greater SCS considered for future NR releases (e.g., in higher frequency bands).

NR also supports carrier aggregation (CA), which was introduced in LTE Rel-10. In CA, the network can configure a "wideband" carrier for the UE based on a number of "component carriers." In the context of CA, the terms "component carrier" (or CC, for short) and "cell" are often used interchangeably. A primary serving cell (PCell) is defined as the "main" cell serving the wireless device such that both data and control signaling can be transmitted over the PCell, while one or more supplementary or secondary serving cells (SCells) are typically used for transmitting data only. A CA-capable UE can be assigned a PCell (or CC) that is always activated, and one or more SCells (or CCs) that can be activated or deactivated dynamically.

The term "symmetric configuration" refers to when the number of CCs in UL and DL is the same, whereas "asymmetric configuration" refers to when the number of CCs is different.

Furthermore, the number of CCs configured within a wideband carrier may be different from the number of CCs seen by a UE. For example, a UE can support more DL CCs than UL CCs, even though the wideband carrier is configured with the same number of UL CCs and DL CCs.

License Assisted Access (LAA) is an LTE feature that uses unlicensed 5-GHz spectrum in combination with licensed spectrum to deliver a performance boost for mobile device users. LAA uses DL carrier aggregation (CA) to combine LTE in licensed and unlicensed bands to provide better data rates and a better user experience. For example, in LAA, the UE's primary cell (PCell) is in a licensed band while the UE's secondary cells (SCells) can be in an unlicensed band. Since LAA operates in the 5-GHz band where Wi-Fi operates, it must be able to co-exist with Wi-Fi by avoiding channels occupied by Wi-Fi users. LAA uses a concept called Listen-before-talk (LBT) that dynamically selects 5-GHz-band channel(s) that is(are) not being used, i.e., a "clear channel." If no clear channel is available, LAA will share a channel fairly with others. As such, LBT is often referred to as clear channel assessment (CCA).

NR Rel-16 includes a feature similar to LTE LAA, referred to as NR-Unlicensed (NR-U). In contrast to LTE LAA, NR-U supports dual-connectivity (DC) and standalone scenarios in which cooperative licensed spectrum is not available. In such scenarios, medium access control (MAC, e.g., random access) and scheduling procedures on unlicensed spectrum are subject to the LBT failures. This was not the case for LTE LAA, since MAC and scheduling procedures were performed in the licensed spectrum where LBT is unnecessary. Note the terms "shared" and "unlicensed" are used synonymously herein when referring to spectrum, unless stated otherwise. Rel-16 NR-U also supports wideband operation, whereby a UE can perform sensing and transmission over a wideband (i.e., much greater than 20 MHz) that includes multiple LBT bandwidths (or sub-bands)

Sidelink (SL) is a type of device-to-device (D2D) communication in which UEs communicate with each other directly rather than indirectly via a 3GPP radio access network (RAN). D2D was first introduced in LTE Rel-12, targeting public safety use cases and proximity-based services (ProSe). Subsequently, various extensions have been introduced to broaden the range of use cases that can benefit from D2D technology. For example, D2D extensions in LTE Rel-14 and Rel-15 include supporting vehicle-to-everything (V2X) communication.

3GPP Rel-16 specifies the NR SL interface and targets advanced V2X services, including four primary groups of use cases: vehicles platooning, extended sensors, advanced driving, and remote driving. The advanced V2X services require a new SL in order to meet the stringent requirements in terms of latency and reliability. The NR SL is designed to provide higher system capacity and better coverage, and to allow for extension to support the future development of even more advanced V2X services and other related services.

Radio resources for NR SL communication are organized into one or more SL resource pools, with each SL resource pool including some number of RBs that span a range of time and frequency. In the frequency domain, each resource pool is divided into sub-channels, where each sub-channel is a group, set, or collection of RBs that are contiguous in frequency.

Furthermore, NR SL is designed such that it is operable both with and without network coverage and with varying degrees of interaction between the UEs (user equipment) and the RAN, including support for standalone, network-less operation. For example, national security and public safety (NSPS) services often need to operate without (or with partial) RAN coverage, such as during indoor firefighting, forest firefighting, earthquake rescue, sea rescue, etc. Network coverage extension is a crucial enabler in these scenarios. 3GPP Rel-17 includes a study item for coverage extension for SL-based communication, including UE-to-network (U2N) relay for cellular coverage extension and UE-to-UE (U2U) relay for SL coverage extension.

It is expected that 3GPP Rel-18 and later releases will include mechanisms for UE transmission and/or reception on multiple channels, including aggregation of multiple carriers in licensed or unlicensed spectrum and wideband transmission spanning multiple channels in unlicensed spectrum. From a lower layer perspective, the first approach appears as multiple transmissions on separate carriers and the second approach appears as a single transmission. It is expected that these approaches will be applicable for UL, DL, and SL.

Various government regulations for unlicensed bands typically set a maximum transmit power (in dBm) and a maximum transmit power spectral density (PSD, in dBm/MHz) for transmitters. It is generally desirable to be able to transmit at the maximum power but if the transmission bandwidth is too narrow, the maximum PSD will be exceeded. To address this issue, NR-U defines interlaced transmissions for UL and DL, whereby the resource blocks (RBs) allocated for the transmission are spread over a larger bandwidth (e.g., system bandwidth, a bandwidth part (BWP), bandwidth of a channel or carrier, bandwidth of set of RBs, etc.). Multiple non-overlapping interlaces span the bandwidth of interest, and each NR-U transmission can be allocated one or more of these interlaces.

Accordingly, there is a need for techniques that allow for performing SL communication in an efficient manner, taking into account the possibility of interlacing of bandwidth portions.

SUMMARY

According to an embodiment, a method for a UE for wireless SL communication with one or more other UEs is provided. The method comprises determining a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a method for a RAN node to facilitate wireless SL communication between a plurality of UEs is provided. The method comprises sending, to the plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a UE for wireless SL communication with one or more other UEs is provided. The UE is configured to determine a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a UE for wireless SL communication with one or more other UEs is provided. The UE comprises processing circuitry and a memory storing computer-executable instructions that, when executed by the processing circuitry, configure the UE to determine a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a RAN node for facilitating wireless SL communication between a plurality of UEs is provided. The RAN node is configured to send, to the plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a RAN node for facilitating wireless SL communication between a plurality of UEs is provided. The RAN node comprises processing circuitry and a memory storing computer-executable instructions that, when executed by the processing circuitry, configure the RAN node to send, to the plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a computer program or computer program product is provided, e.g., in the form of a non-transitory, computer readable medium. The computer program or computer program product comprises computer-executable instructions that, when executed by processing circuitry of a UE, configure the UE node to determine a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

According to a further embodiment, a computer program or computer program product is provided, e.g., in the form of a non-transitory, computer readable medium. The computer program or computer program product comprises computer-executable instructions that, when executed by processing circuitry of a RAN node, configure the RAN node to send, to the plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

These and other objects, features, and advantages of embodiments of the present disclosure will become apparent upon reading the following Detailed Description in view of the Drawings briefly described below.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows exemplary NR user plane (UP) and control plane (CP) protocol stacks.

Figure 2 illustrates a high-level views of an exemplary 5G/NR network architecture.

Figure 3 shows an exemplary intra-band CA arrangement in which a UE is configured with three CCs in a single frequency band.

Figure 4 shows an exemplary LTE CCA procedure performed by a UE or network node wanting to transmit on a channel in unlicensed spectrum.

Figure 5 shows a comparison of transmissions on contiguous RBs and interlaced RBs within a 20-MHz channel bandwidth.

Figure 6 shows an example arrangement of an 80-MHz system bandwidth in unlicensed spectrum, consisting of four (4) 20-MHz channels.

Figure 7 shows an example where a transmission is allocated two interlaces within a 20-MHz channel.

Figure 8 shows three exemplary network coverage scenarios for two UEs and a gNB serving a cell.

Figure 9 shows an exemplary SL resource pool with three (3) sub-channels, each of the consisting of four (4) RBs in frequency and a (periodically repeating) number of slots in time.

Figure 10 shows an exemplary time-frequency grid for SL communication in a channel.

Figure 11 illustrates examples of SL resource reservation for non-periodic TB initial transmissions, blind retransmissions, and retransmissions due to HARQ feedback.

Figures 12-14 show various exemplary mappings for a 20-MHz channel arranged as a SL resource pool with different numbers of sub-channels, according to various embodiments of the present disclosure.

Figures 15-16 show various exemplary mappings for a 40-MHz system bandwidth arranged as two 20-MHz channels, each comprising a SL resource pools with Nsubch = 3 sub-channels, according to various embodiments of the present disclosure.

Figure 17 shows an exemplary mapping for a 20-MHz channel arranged as a SL resource pool with Nsubch = 3 sub-channels, according to some embodiments of the present disclosure.

Figures 18-19 show various exemplary mappings for a 40-MHz system bandwidth arranged as two 20-MHz channels, each comprising a SL resource pools with Nsubch = 3 sub-channels, according to various embodiments of the present disclosure.

Figure 20 shows a flow diagram of an exemplary method for a UE (*e.g.,* wireless device), according to various embodiments of the present disclosure.

Figure 21 shows a flow diagram of an exemplary method for a RAN node (*e.g.,* base station, eNB, gNB, ng-eNB, etc.), according to various embodiments of the present disclosure.

Figure 22 shows a communication system according to various embodiments of the present disclosure.

Figure 23 shows a UE according to various embodiments of the present disclosure.

Figure 24 shows a network node according to various embodiments of the present disclosure.

Figure 25 shows host computing system according to various embodiments of the present disclosure.

Figure 26 is a block diagram of a virtualization environment in which functions implemented by some embodiments of the present disclosure may be virtualized.

Figure 27 illustrates communication between a host computing system, a network node, and a UE via multiple connections, at least one of which is wireless, according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Some of the embodiments contemplated herein will now be described more fully with reference to the accompanying drawings. Other embodiments, however, are contained within the scope of the subject matter disclosed herein, the disclosed subject matter should not be construed as limited to only the embodiments set forth herein; rather, these embodiments are provided by way of example to convey the scope of the subject matter to those skilled in the art.

Generally, all terms used herein are to be interpreted according to their ordinary meaning in the relevant technical field, unless a different meaning is clearly given and/or is implied from the context in which it is used. All references to a/an/the element, apparatus, component, means, step, *etc.* are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, *etc.*, unless explicitly stated otherwise. The steps of any methods disclosed herein do not have to be performed in the exact order disclosed, unless a step is explicitly described as following or preceding another step and/or where a step must necessarily follow or precede another step due to some dependency. Any feature of any of the embodiments disclosed herein may be applied to any other embodiment, wherever appropriate. Likewise, any advantage of any of the embodiments may apply to any other embodiments, and vice versa. Other objectives, features, and advantages of the enclosed embodiments will be apparent from the following description.

Furthermore, the following terms are used throughout the description given below:

- Radio Node: As used herein, a “radio node” can be either a radio access node or a wireless device.”
- Node: As used herein, a “node” can be a network node or a wireless device.
- Radio Access Node: As used herein, a “radio access node” (or equivalently “radio network node,” “radio access network node,” or “RAN node”) can be any node in a radio access network (RAN) of a cellular communications network that operates to wirelessly transmit

and/or receive signals. Some examples of a radio access node include, but are not limited to, a base station (*e.g.*, a New Radio (NR) base station (gNB) in a 3GPP Fifth Generation (5G) NR network or an enhanced or evolved Node B (eNB) in a 3GPP LTE network), base station distributed components (*e.g.*, CU and DU), a high-power or macro base station, a low-power base station (*e.g.*, micro, pico, femto, or home base station, or the like), an integrated access backhaul (IAB) node, a transmission point, a remote radio unit (RRU or RRH), and a relay node.

- Core Network Node: As used herein, a "core network node" is any type of node in a core network. Some examples of a core network node include, *e.g.*, a Mobility Management Entity (MME), a serving gateway (SGW), a Packet Data Network Gateway (P-GW), an access and mobility management function (AMF), a session management function (AMF), a user plane function (UPF), a Service Capability Exposure Function (SCEF), or the like.
- Wireless Device: As used herein, a "wireless device" (or "WD" for short) is any type of device that has access to (*i.e.*, is served by) a cellular communications network by communicate wirelessly with network nodes and/or other wireless devices. Communicating wirelessly can involve transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information through air. Some examples of a wireless device include, but are not limited to, smart phones, mobile phones, cell phones, voice over IP (VoIP) phones, wireless local loop phones, desktop computers, personal digital assistants (PDAs), wireless cameras, gaming consoles or devices, music storage devices, playback appliances, wearable devices, wireless endpoints, mobile stations, tablets, laptops, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), smart devices, wireless customer-premise equipment (CPE), mobile-type communication (MTC) devices, Internet-of-Things (IoT) devices, vehicle-mounted wireless terminal devices, *etc.* Unless otherwise noted, the term "wireless device" is used interchangeably herein with the term "user equipment" (or "UE" for short).
- Network Node: As used herein, a "network node" is any node that is either part of the radio access network (*e.g.*, a radio access node or equivalent name discussed above) or of the core network (*e.g.*, a core network node discussed above) of a cellular communications network. Functionally, a network node is equipment capable, configured, arranged, and/or operable to communicate directly or indirectly with a wireless device and/or with other network nodes or equipment in the cellular communications network, to enable and/or provide wireless access to the wireless device, and/or to perform other functions (*e.g.*, administration) in the cellular communications network.

Note that the description herein focuses on a 3GPP cellular communications system and, as such, 3GPP terminology or terminology similar to 3GPP terminology is oftentimes used. However, the concepts disclosed herein are not limited to a 3GPP system. Furthermore, although the term “cell” is used herein, it should be understood that (particularly with respect to 5G NR) beams may be used instead of cells and, as such, concepts described herein apply equally to both cells and beams.

In the present disclosure, it is considered that it is desirable to re-use to the NR-U UL/DL interlace technique for NR SL operation in unlicensed spectrum. However, various problems, issues, and/or difficulties arise when trying to adapt these interlace techniques to the sub-channel structure of the SL resource pools.

Embodiments of the present disclosure provide specific improvements to SL (or D2D) communication between UEs in unlicensed or shared spectrum, such as by providing, enabling, and/or facilitating solutions to overcome exemplary problems summarized above and described in more detail below.

Some embodiments include exemplary methods (e.g., procedures) for a UE configured for wireless SL communication with one or more other UEs in a radio access network (RAN).

These exemplary methods can include receiving, from a RAN node, a configuration for one or more SL resource pools corresponding to respective one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of resource blocks (RBs) that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels. Accordingly, the RBs may be spread over the bandwidth of the one or more channels, so that the RBs are no longer contiguous. The spreading can result in a more or less uniform distribution of the RBs over the bandwidth of the one or more channels. However, distribution according to irregular patterns are possible as well. Further, it is noted that some of the RBs could also remain contiguous in the interlaced resource allocations.

In some embodiments, these exemplary methods can also include the following operations: selecting a sub-channel from at least one SL resource pool that corresponds to at least one channel; determining RBs comprising a first one of the interlaced resource allocations based on the selected at least one sub-channel and the first mapping; and performing wireless SL communication using the RBs comprising the first interlaced resource allocation.

In some embodiments, performing wireless SL communication includes one or more of the following operations:

- performing radio measurements on the RBs comprising the first interlaced resource allocation;
- based on the radio measurements, determining whether the sub-channel corresponding to the first interlaced resource allocation is free, busy, or reserved; and
- transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation.

In some embodiments, the configuration is for a single SL resource pool corresponding to a single channel and the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations. In other embodiments, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the first mapping is between a first plurality of sub-channels – in each of the SL resource pools – and a first plurality of interlaced resource allocations.

In some of these embodiments, in each SL resource pool, each sub-channel includes a second plurality of RBs and each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

In other of these embodiments, in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs and the exception sub-channel includes less than the second plurality of RBs. In such case, each interlaced resource allocation comprises RBs that are variably spaced in frequency.

In some variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation. In some further variants, in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel and one of the following applies:

- the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool; or
- the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool.

In some of these embodiments, each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels and the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations. For example, each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

In some variants, in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel and for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel.

In other variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels. In each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel. The second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel, while the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool.

In some of the above-described variants, transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation in block 2040 includes one of the following with respect to the additional RBs comprising the first interlaced resource allocation:

- transmitting, in the additional RBs, a repetition of data transmitted in the sub-channel RBs that are mapped to the first interlaced resource allocation; or
- refraining from transmitting in one or more of the additional RBs.

In some embodiments, the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

- the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or
- the RBs comprising sub-channels of a subset of the plurality of channels (e.g., a single channel), and a subset of the plurality of interlaced resource allocations (e.g., a single allocation) that span the subset of the plurality of channels.

Other embodiments include exemplary methods (e.g., procedures) for a RAN node configured to facilitate wireless SL communication between a plurality of UEs. In general, these exemplary methods are complementary to the exemplary methods for a UE, summarized above.

These exemplary methods can include sending, to a plurality of UEs, a configuration for one or more SL resource pools corresponding to respective one or more channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

In various embodiments, the configuration, the one or more channels and corresponding SL resource pools, the sub-channels, and the mapping can have any of the corresponding features, content, and/or characteristics summarized above for UE embodiments.

In some embodiments, the configuration sent to a first UE is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the configuration sent to a second UE includes is for a subset of the plurality of SL resource pools corresponding to a respective subset of the plurality of channels.

Other embodiments include UEs (e.g., wireless devices) and RAN nodes (e.g., base stations, eNBs, gNBs, ng-eNBs, etc.) configured to perform operations corresponding to any of the exemplary methods described herein. Other embodiments include non-transitory, computer-readable media storing program instructions that, when executed by processing circuitry, configure such UEs and RAN nodes to perform operations corresponding to any of the exemplary methods described herein.

These and other embodiments described herein provide mapping of interlaces for transmission on unlicensed spectrum to sub-channels in SL resource pools, thereby facilitating use of SL interlaced transmission in unlicensed spectrum. Mapping between sub-channel and interlace facilitates reuse legacy procedures for SL resource allocation and transmission. Embodiments also facilitate mapping of additional RBs that do not belong to a sub-channel or that belong to a sub-channel with a smaller size, as well as to ensuring continuity in interlaces that cross adjacent channels. In this manner, embodiments can extend a basic mapping (i.e., for a single channel) over a larger band (i.e., with multiple channels). In this manner, embodiments facilitate SL operation in unlicensed spectrum, thereby enabling increased SL data rates needed for advanced SL services targeted by future 3GPP releases.

Figure 1 shows an exemplary configuration of NR user plane (UP) and control plane (CP) protocol stacks between a UE, a gNodeB (gNB, e.g., base station), and an access and mobility management function (AMF) in the 5G core network (5GC). Physical (PHY), Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP) layers between the UE and the gNB are common to UP and CP. The PDCP layer provides ciphering/deciphering, integrity protection, sequence numbering, reordering, and duplicate detection for CP and UP.

On CP side, the non-access stratum (NAS) layer is between UE and AMF and handles UE/gNB authentication, mobility management, and security control. The RRC layer sits below NAS in the UE but terminates in the gNB rather than the AMF. RRC controls communications between UE and gNB at the radio interface as well as the mobility of a UE between cells in the NG-RAN. RRC also broadcasts system information (SI) and establishes, configures, maintains, and releases DRBs and Signaling Radio Bearers (SRBs) used by UEs. Additionally, RRC controls addition, modification, and release of carrier aggregation (CA) and dual-connectivity (DC) configurations for UEs. RRC also performs various security functions such as key management.

After a UE is powered ON it will be in the RRC_IDLE state until an RRC connection is established with the network, at which time the UE will transition to RRC_CONNECTED state (*e.g.,* where data transfer can occur). The UE returns to RRC_IDLE after the connection with the network is released. In RRC_IDLE state, the UE's radio is active on a discontinuous reception (DRX) schedule configured by upper layers. During DRX active periods (also referred to as "DRX On durations"), an RRC_IDLE UE receives SI broadcast in the cell where the UE is camping, performs measurements of neighbor cells to support cell reselection, and monitors a paging channel on physical DL control channel (PDCCH) for pages from 5GC via gNB. A UE in RRC_IDLE state is not known to the gNB serving the cell where the UE is camping. However, NR RRC includes an RRC_INACTIVE state in which a UE is known (e.g., via context) by the serving gNB.

Figure 2 shows a high-level view of an exemplary 5G network architecture, including a Next Generation Radio Access Network (NG-RAN) 299 and a 5G Core (5GC) 298. As shown in the figure, NG-RAN 299 can include gNBs 210 (*e.g.*, 210a,b) and ng-eNBs 220 (*e.g.*, 220a,b) that are interconnected with each other via respective Xn interfaces. The gNBs and ng-eNBs are also connected via the NG interfaces to 5GC 298, more specifically to the Access and Mobility Management Function (AMF, *e.g.*, 230a,b) via respective NG-C interfaces and to the User Plane Function (UPF, *e.g.*, 240a,b) via respective NG-U interfaces. Moreover, the AMFs can communicate with one or more policy control functions (PCFs, e.g., 250a,b) and network exposure functions (NEFs, e.g., 260a,b).

Each of the gNBs 210 can support the NR radio interface including frequency division duplexing (FDD), time division duplexing (TDD), or a combination thereof. In contrast, each of ng-eNBs 220 can support the LTE radio interface but, unlike conventional LTE eNodeBs (eNBs), connect to the 5GC via the NG interface. Each of the gNBs and ng-eNBs can serve a geographic coverage area including one more cells, including cells 211a-b and 221a-b shown as exemplary in Figure 2. The gNBs and ng-eNBs can also use various directional beams to provide coverage in the respective cells. Depending on the particular cell in which it is located, a UE 205 can communicate with the gNB or ng-eNB serving that cell via the NR or LTE radio interface, respectively.

The gNBs shown in Figure 2 can include a central (or centralized) unit (CU or gNB-CU) and one or more distributed (or decentralized) units (DU or gNB-DU), which can be viewed as logical nodes. CUs host higher-layer protocols and perform various gNB functions such controlling the operation of DUs, which host lower-layer protocols and can include various subsets of the gNB functions. As such, each of the CUs and DUs can include various circuitry needed to perform their respective functions, including processing circuitry, communication interface circuitry (*e.g.*, for communication via Xn, NG, radio, etc. interfaces), and power supply circuitry. Moreover, the terms "central unit" and "centralized unit" can be used interchangeably, as can the terms "distributed unit" and "decentralized unit."

A CU connects to its associated DUs over respective F1 logical interfaces. A CU and associated DUs are only visible to other gNBs and the 5GC as a gNB, *e.g.*, the F1 interface is not visible beyond a CU. A CU can host higher-layer protocols such as F1 application part protocol (F1-AP), Stream Control Transmission Protocol (SCTP), GPRS Tunneling Protocol (GTP), Packet Data Convergence Protocol (PDCP), User Datagram Protocol (UDP), Internet Protocol (IP), and Radio Resource Control (RRC) protocol. In contrast, a DU can host lower-layer protocols such as Radio Link Control (RLC), Medium Access Control (MAC), and physical-layer (PHY) protocols.

NR DL and UL physical resources are organized into equal-sized 1-ms subframes. A subframe is further divided into multiple slots of equal duration, with each slot including multiple OFDM-based symbols. An NR slot can include 14 OFDM symbols for normal cyclic prefix and 12 symbols for extended cyclic prefix. A resource block (RB) consists of a group of 12 contiguous OFDM subcarriers for a duration of a 12- or 14-symbol slot. A resource element (RE) corresponds to one OFDM subcarrier during one OFDM symbol interval. An NR slot can also be arranged with various time-division duplexing (TDD) arrangements of UL and DL symbols. These TDD arrangements include:

- DL-only (*i.e.*, no UL transmission) slot with transmission late-start in symbol 1;
- DL-heavy, with one UL symbol and guard periods before and after the UL symbol to facilitate change of transmission direction;
- UL-heavy, with a single UL symbol that can carry DL control information; and
- UL-only with transmission on-time start in symbol 0 and the initial UL symbol usable to carry DL control information.

In addition to providing coverage via cells as in LTE, NR networks also provide coverage via "beams." In general, a downlink (DL, i.e., network to UE) "beam" is a coverage area of a network-transmitted reference signal (RS) that may be measured or monitored by a UE. In NR, for example, RS can include any of the following: synchronization signal/PBCH block (SSB), channel state information RS (CSI-RS), tertiary reference signals (or any other sync signal), positioning RS (PRS), demodulation RS (DMRS), phase-tracking reference signals (PTRS), *etc.* In general, SSB is available to all UEs regardless of the state of their connection with the network, while other RS (*e.g.,* CSI-RS, DM-RS, PTRS) are associated with specific UEs that have a network connection.

These RS are carried by various REs within DL RBs, which also carry various DL physical channels such as physical DL control channel (PDCCH), physical DL shared channel (PDSCH), physical broadcast channel (PBCH), etc. A UE can also transmit various UL physical channels and signals that are carried within UL RBs, such as physical UL control channel (PUCCH), physical UL shared channel (PUSCH), physical random access channel (PRACH), sounding RS (SRS), etc.

NR supports the combination of carrier aggregation (CA) and bandwidth parts (BWPs). For example, a UE can be configured with multiple CCs and up to four DL and four UL BWPs on each CC. On each CC, the UE can have one configured DL BWP and one configured UL BWP active at any given time. Common resource blocks (CRBs) within a carrier bandwidth are numbered from 0 to n-1, where n is the number of RBs comprising the carrier bandwidth. Each BWP configured for a UE may start at CRBi, i=0…n-1, according to the configured BWP size and location.

Additionally, CA can be configured as interband, intraband contiguous, or intraband non-contiguous. Intraband means that the aggregated CCs reside in the same frequency band, and are either contiguous (e.g., adjacent) or non-contiguous (e.g., separated). In contrast, interband CCs are located in different frequency bands.

Figure 3 shows an exemplary intra-band CA arrangement whereby a UE is configured with three CCs in a single frequency band, labeled CCi, i=1-3. The UE is also configured with four BWPs in each CCi, labelled Bj.i, j=1-4. A single BWP is shown as active for each CC, in particular B1.3, B2.3, and B3.2. Note the arrangement shown in Figure 3 can apply to DL or UL.

Besides conventional operation in licensed (i.e., exclusive) spectrum, NR networks also can operate in unlicensed bands in shared spectrum, referred to generally as NR-U. Operation in unlicensed bands introduces a unique set of rules intended to promote spectrum sharing with otherwise competing transceivers. These rules promote an etiquette or behavior that facilitates spectrum sharing and/or co-existence. According to a common coexistence technique, for a node (e.g., UE or base station) to be allowed to transmit in unlicensed spectrum, it typically needs to perform a listen-before-talk (LBT) or a clear channel assessment (CCA). For example, in the 5 GHz band, the sensing is done over 20-MHz channels. In general, the MAC layer initiates a transmission and requests the PHY layer to initiate the LBT procedure. After completion, the PHY layer indicates the LBT outcome (e.g., success or failure). This procedure can include sensing the medium as idle for a number of time intervals, which can be done in various ways including energy detection, preamble detection, or virtual carrier sensing.

LBT has become well-known and popular due to ubiquitous use by Wireless LANs (also known as "WiFi"), even though most regulatory agencies did not enforce LBT requirements. The introduction of LTE LAA and subsequent definition of LTE LAA regulations ensured LBT functionality was required by all radio transceivers, regardless of whether they were WiFi or LTE LAA. Energy detection (ED) thresholds were defined, simulated, debated, and soon became part of the regulatory specifications to be met by all devices that operate in unlicensed bands.

As an example of energy detection (ED), a channel is assessed to be idle when the received energy or power during the sensing time duration is below a certain ED threshold; otherwise, the channel is considered busy. Regulatory requirements in some regions specify the maximum allowed ED threshold, thus setting a limit on transmitter behavior. An example ED threshold is -72 dBm. In some cases, the ED threshold may depend on the channel bandwidth, e.g., -72 dBm 20 MHz bandwidth, -75 dBm for 10 MHz bandwidth, etc. If the channel is assessed as "busy" then the prospective transmitter (i.e., UE or network node) is required to defer transmission.

When sensing a shared channel, a UE may also determine a channel busy ratio (CBR). In general, CBR is the ratio of the number of times in a specified time duration (e.g., 0.1 sec, 1 sec, etc.) that a UE assessed the channel as busy (e.g., based on ED thresholds) to the total number of times the UE assessed the channel in the specified time duration.

Figure 4 shows an exemplary LTE CCA procedure performed by a UE or network node wanting to transmit on a channel in unlicensed spectrum. In this procedure, the prospective transmitter initially senses the channel busy for a duration. After a deferral period, the transmitter senses the channel to be idle in the period labelled "s" (for sensing). For example, s = 25 μs. After a backoff time following the idle sensing, the transmitter has a transmission opportunity (TXOP) or a channel occupancy time (COT) during which it may transmit a signal, with the COT being less than a maximum COT (MCOT) that depends of regional rules or laws, the sensing period s, etc. For example, a typical COT is 1-10 ms based on a MCOT of 10 ms. The backoff time may be a deterministic value or a probabilistic value (e.g., selected from a random distribution).

It is expected that NR-U will support operation over a wide bandwidth (i.e., much larger than 20 MHz), similar to NR in licensed spectrum. This can be achieved in two different ways: 1) CA with configuration of multiple serving cells (e.g., four with 20 MHz bandwidth each); and 2) configuration of a single wideband serving cell with bandwidth of an integer multiple of 20 MHz (e.g., 80 MHz). These approaches were studied for NR-U in Rel-16, along with potential scheduling constraints and/or feasibility of operating the wideband carrier when LBT is unsuccessful in one or more LBT sub-bands within the wideband carrier. It was assumed that CCA is performed in units of 20MHz, at least for operation in 5GHz band.

As used herein, “wideband operation” refers to UE communication within a wideband channel with a bandwidth larger than 20 MHz in licensed and/or unlicensed spectrum, e.g., based on outcome of a CCA procedure. The wideband channel includes two or more (i.e., an integer number of) non-overlapping sub-bands, with each sub-band comprising a set of RBs within an ~20 MHz portion of the channel. The respective sub-bands may be uniform (e.g., of identical bandwidth) but may be separately allocated in UL and DL. Each of the sub-bands may use a different combination of radio-related parameters such as SCS, OFDM symbol duration, cyclic prefix (CP) duration, etc. In the context of a wideband channel, the terms “channel”, “sub-band”, and “carrier” are used synonymously to denote a constituent part (e.g., 20 MHz) of the wideband channel.

The ED technique summarized above is sensitive to leakage from adjacent channels. That is, a UE transmitting in a first channel will leak a small amount of energy into an adjacent channel (or more than one adjacent channel). UEs operating in the adjacent channel may incorrectly detect the adjacent channel as busy based on this leaked energy, particularly when no actual transmission is occurring in the adjacent channel. This effect is sometimes referred to as LBT blocking (due to adjacent-channel leakage).

To mitigate the LBT blocking problem, the 5G NR system defines a resource block (RB) set and an intra-cell guard band. Figure 6 shows an example arrangement of an 80-MHz system bandwidth in unlicensed spectrum, consisting of four (4) 20-MHz channels. In this arrangement, the RB sets are the four groups of 50 RBs that are within the respective channels. In addition, there is an intra-cell guard band between each pair of adjacent channels. This is a small number of additional RBs at the edge of a channel or at the edges of two adjacent channels. A transmission on only one of two adjacent channels cannot make use of the RBs in the intra-cell guard band, but a transmission that uses both adjacent channels may use the RBs in the intra-cell guard band. In this example shown in Figure 6, the intracell guard bands are non-uniform in width.

Various government regulations for unlicensed bands typically set a maximum transmit power (in dBm) and a maximum transmit power spectral density (PSD, in dBm/MHz) for transmitters. It is generally desirable to be able to transmit at the maximum power but if the transmission bandwidth is too narrow, the maximum PSD will be exceeded. Some regions also have occupied channel bandwidth (OCB) regulations for unlicensed spectrum. In general, OCB is defined as the bandwidth containing 99% of the transmission signal energy and is required to be at least 80% of the nominal channel bandwidth

To address these issues, NR-U defines interlaced transmissions for UL and DL, whereby the resource blocks (RBs) allocated for the transmission are spread over a larger bandwidth (e.g., system bandwidth, a bandwidth part (BWP), bandwidth of a channel or carrier, bandwidth of set of RBs, etc.). Multiple non-overlapping interlaces span the bandwidth of interest, and each NR-U transmission can be allocated one or more of these interlaces. Figure 5 shows a comparison of transmissions on contiguous RBs and interlaced RBs within a 20-MHz channel bandwidth.

Note that non-interlaced and non-contiguous are used synonymously in this context, as are the terms transmission and allocation (e.g., a transmission takes place on an allocation). When contiguous transmissions are used, an allocation typically consists of a starting RB and a bandwidth in term of RBs. When interlaced transmissions are used, an allocation typically consists of one or more interlaces. In other words, multiple interlaces are defined for the channel bandwidth and the transmission is allocated one or more of them. Figure 7 shows an example where a transmission is allocated two interlaces within a 20-MHz channel, denoted by checkered boxes and gridded boxes.

As briefly mentioned above, 3GPP Rel-16 specifies the NR sidelink (SL) interface and targets advanced V2X services including use cases such as vehicles platooning, extended sensors, advanced driving, and remote driving. The advanced V2X services require a new SL to meet service requirements of low latency and high reliability. The NR SL is designed to provide higher system capacity and better coverage, and to allow for extension to support the future development of even more advanced V2X services and other related services.

In general, a V2X UE can support unicast communication via the uplink/downlink radio interface (also referred to as “Uu”) to a 3GPP RAN, such as the LTE Evolved-UTRAN (E-UTRAN) or the NG-RAN. A V2X UE can also support SL unicast over the PC5 interface. In addition to Uu and PC5 interfaces, the V2X UEs can communicate with a ProSe (PROximity-based SErvices) network function (NF) via respective PC3 interfaces. Communication with the ProSe NF requires a UE to establish a connection with the RAN, either directly via the Uu interface or indirectly via PC5 and another UE’s Uu interface. The ProSe function provides the UE various information for network related actions, such as service authorization and provisioning of PLMN-specific information (e.g., security parameters, group IDs, group IP addresses, out-of-coverage radio resources, etc.).

Figure 8 shows three exemplary network coverage scenarios for two UEs (810, 820) and a gNB (830) serving a cell. In the full coverage scenario (left), both UEs are in the coverage of the cell, such that they both can communicate with the gNB via respective Uu interfaces and directly with each other via the PC5 interface. In the partial coverage scenario (center), only one of the UEs is in coverage of the cell, but the out-of-coverage UE can still communicate with the gNB indirectly via the PC5 interface with the in-coverage UE. In the out-of-coverage scenario, both UEs can only communicate with each other via the PC5 interface.

In general, the term "SL standalone" refers to direct communication between two SL-capable UEs (e.g., via PC5) in which source and destination are the UEs themselves. In contrast, the term "SL relay" refers to indirect communication between a network node and a remote UE via a first interface (e.g., Uu) between the network node an intermediate (or relay) UE and a second interface (e.g., PC5) between the relay UE and the remote UE. In this case the relay UE is neither the source nor the destination.

In general, an "out-of-coverage UE" is one that cannot establish a direct connection to the network and must communicate via either SL standalone or SL relay. UEs that are in coverage can be configured by the network (e.g., gNB) via RRC signaling and/or broadcast system information, either directly (via Uu interface) or indirectly (via PC5 interface and relay UE Uu interface). Out-of-coverage UEs rely on a (pre-)configuration available in their SIMs. These pre-configurations are generally static but can be updated by the network when a UE is in coverage. A "peer UE" refers to a UE that can communicate with the out-of-coverage UE via SL standalone or SL relay (in which case the peer UE is also a relay UE).

3GPP Rel-17 will include further enhancements for NR SL. These include coverage extension for SL-based communication, including UE-to-network (U2N) relay for cellular coverage extension and UE-to-UE (U2U) relay for SL coverage extension. Other improvements include performance of power-limited UEs (e.g., pedestrian UEs, first responder UEs, etc.). These improvements address various use cases including National Security and Public Safety (NSPS), Network Controlled Interactive Services (NCIS), etc.

NR SL also includes enhanced channel sensing and resource selection procedures relative the LTE LAA. NR SL also provides congestion control and QoS management to achieve a higher connection density than LTE LAA. To enable these and other enhancements, NR SL includes the following new physical channels and RS):

- PSSCH (Physical SL Shared Channel, SL version of PDSCH): PSSCH is transmitted by a SL transmitter UE, and conveys SL, SIBs for RRC configuration, and a part of the SL control information (SCI, SL version of DL control information).
- PSFCH (Physical SL feedback channel): The PSFCH is transmitted by a SL receiver UE for unicast and groupcast, and conveys one bit information over one RB for HARQ ACK or NACK. In addition, CSI is carried in a MAC control element (CE) over PSSCH instead of via PSFCH.
- PSCCH (Physical SL Common Control Channel, SL version of PDCCH): When traffic to be sent to a receiver UE arrives at a transmitter UE, it should first send the PSCCH to convey a part of SCI to be decoded by any UE for channel sensing purpose. This part of

SCI includes reserved time-frequency resources for transmissions, DMRS pattern and antenna port, etc.

- SL Primary/Secondary Synchronization Signal (S-PSS/S-SSS): SL primary and secondary synchronization signals (S-PSS and S-SSS, respectively) are supported similar to DL PSS/SSS. By detecting S-PSS and S-SSS, a UE is able to identify the SL synchronization identity (SSID) of the sending UE (called "synchronization source") and its associated characteristics. A process of acquiring timing and frequency synchronization and UE SSIDs is called initial cell search. Note that the UE sending S-PSS/S-SSS may not be necessarily involved in other SL transmissions. There are two S-PSS sequences and 336 S-SSS sequences, forming a total of 672 SSIDs in a cell.
- Physical SL Broadcast Channel (PSBCH): PSBCH is transmitted along with the S-PSS/S-SSS as a synchronization signal/PSBCH block (SSB). The SSB has the same numerology as PSCCH/PSSCH on that carrier, and should be transmitted within the bandwidth of the configured bandwidth part (BWP). PSBCH conveys synchronization-related information such as direct frame number (DFN), indication of the slot and symbol level time resources for SL transmissions, in-coverage indicator, etc. SSB is transmitted every 160 ms.
- DMRS, PT-RS, CSI-RS: These RS supported by NR DL are also supported on NL SL, including that PT-RS is only applicable for transmissions in frequency range 2 (FR2, e.g., above 6GHz).

As mentioned above, unlike DCI on PDCCH, only a first part (or stage) of SCI is sent on PSCCH. This first stage is used for channel-sensing purposes and can be read by all UEs. The second stage is sent on PSSCH and includes scheduling and control information such as an 8-bit source ID, 16-bit destination ID, new data indicator (NDI), redundancy version (RV), and HARQ process ID. This second part can be decoded only by the intended receiver UE.

Radio resources for SL communication are organized into an SL resource pool spanning both time and frequency domains. In the time domain, the SL resource pool consists of NR slots indexed in an ascending order from zero to a maximum index value. Once this maximum index is reached, the slot indexing is repeated starting again from zero, and so on. In the frequency domain, each resource pool is divided into sub-channels, where each sub-channel is a group, set, or collection of RBs that are contiguous in frequency. Figure 9 shows an exemplary SL resource pool with three (3) sub-channels, each of the consisting of four (4) RBs in frequency and a (periodically repeating) number of slots in time.

Two types of resource allocation modes are supported for NR SL between UEs. In NR SL resource allocation mode 1, all SL transmissions between UEs are scheduled by the network (e.g., a serving gNB) using a configured grant or a dynamic grant, which are described below.

When the traffic to be sent over SL arrives at a transmitter UE, this UE launches a four-message procedure to request SL resources from a gNB: UL scheduling request (SR), DL grant for buffer status report (BSR), UL BSR, and DL grant for data comprising BSR. During the resource request procedure, a gNB may allocate a SL radio network temporary identifier (SL-RNTI) to the transmitter UE. If a SL resource request is granted, the gNB indicates the resource allocation for PSCCH and the PSSCH in DCI on PDCCH with a CRC scrambled with the SL-RNTI. When a transmitter UE receives such a DCI, it UE can obtain the grant only by descrambling the CRC using the assigned SL-RNTI. A transmitter UE then indicates the time-frequency resources and the transmission scheme of the allocated PSSCH in the PSCCH, and launches PSCCH and PSSCH on the resources allocated for SL transmissions. A transmitter UE can only transmit a single TB on a grant obtained from a gNB, making dynamic grants suitable only for traffic with loose latency requirements.

For the traffic with a strict latency requirement, performing the four-message exchange procedure to request SL resources induces unacceptable latency. Thus, prior to anticipated traffic arrival, a transmitter UE may request a set of resources via the four-message exchange procedure mentioned above. The gNB can reserve periodic SL resources according to the request and convey this to the UE in a SL configured grant, similar to an UL configured grant. When the anticipated traffic arrives, the transmitter UE can launch the PSCCH and the PSSCH during the next occasion of the resources of the configured grant. This process is also known as grant-free transmission.

The network (e.g., gNB) can provide a UE with SL configured grant via RRC. SL configured grants typically allocate resources having a periodic, semi-persistent pattern. Two types of configured SL grants are available, i.e., types 1 and 2. In type 2, the network can activate/deactivate the RRC-configured grant using DCI signaling. In other cases, the network may select the resources used for transmission but may give the transmitting SL UE some freedom to select some of the transmission parameters, possibly with some restrictions

In SL resource allocation mode 2, the resource allocation is performed by UE itself, e.g., autonomously based on sensing the carrier/resource pool for availability. In particular, the UE determines SL resource pool(s) by decoding sidelink control information (SCI) received from other UEs and/or by energy sensing, and selects a set of idle/available resources to use for its transmission of PSCCH and PSSCH. In this mode, there may be no intervention by the network (e.g., out of coverage, unlicensed carriers without a network deployment, etc.) or very minimal intervention by the network (e.g., configuration of pools of resources, etc.).

Note that Mode 1 and Mode 2 only describe the behavior of a UE when acting as a SL transmitter. A SL receiver UE behaves the same regardless of SL transmitter mode. Moreover, signals used by SL transmitters operating in Mode 1 and Mode 2 transmitters are identical.

Figure 10 shows an exemplary time-frequency grid for SL communication in a channel (labelled "Channel 1"). In particular, the first stage of SCI is carried by PSCCH in a first set of time-frequency resources, the second stage of SCI is carried by PSSCH in a second set of time-frequency resources, and the data payload scheduled by SCI is carried in a third set of time-frequency resources. For example, the SCI carries a scheduling assignment (SA) for receiving the data payload.

To further minimize the latency of the HARQ ACK/NACK feedback and subsequent retransmissions, the transmitter UE may also reserve PSCCH/PSSCH resources for retransmissions. To improve probability of successful one-shot transport block (TB) decoding and thereby reduce retransmissions, the transmitter UE may repeat a TB transmission prior to receiving HARQ feedback – a mechanism known as blind retransmission. Thus, when traffic arrives at a transmitter UE, it should select resources for PSSCH associated with PSCCH for initial transmission and blind retransmissions, and PSSCH associated with the PSCCH for retransmissions.

Every PSSCH transmission and can reserve for up to two retransmissions for the same TB. In addition, the same first stage SCI can reserve the same radio resources (i.e., 1-3 RBs) for transmission of a (single) different TB. Figure 11 illustrates examples of SL resource reservation for non-periodic TB initial transmissions, blind retransmissions, and retransmissions due to HARQ feedback.

It is important to note that, although the SL transmitter UE may select resources for transmission of multiple TBs, only a small subset of them are reserved at a time. In other words, the SL transmitter UE reserves its selected resources in steps. Whether the resources reserved for retransmission of a TB are used or not typically depends on SL HARQ feedback. This is described in the following section.

Since each SL transmitter UE autonomously selects resources in mode 2 as described above, there is a need to prevent different transmitter UEs from selecting the same resources. One mode-2 resource selection procedure is based on a channel sensing technique that involves measuring RSRP on different subchannels. This technique requires knowledge of DMRS power levels for different UEs on PSSCH or PSCCH, depending on the configuration. This information is known only after receiving SCI from all other UEs, and adds to the overall complexity of this channel sensing and selection technique.

3GPP document RP-213678 discusses NR SL evolution in 3GPP Rel-18. For commercial SL applications, two key requirements increased data rate and support for additional carrier frequencies. For example, increased data rate enables sharing of sensor (e.g., video) information between vehicles to facilitate driving automation. Data rates of these use cases exceed of what was possible with NR SL Rel-17.

Thus, it is expected that 3GPP Rel-18 and later releases will include mechanisms for UE SL transmission and/or reception on multiple channels, including aggregation of multiple carriers (e.g., CA) in licensed or unlicensed spectrum and wideband transmission spanning multiple channels in unlicensed spectrum. From a lower layer perspective, the first approach appears as multiple transmissions on separate carriers and the second approach appears as a single transmission. It is also expected that channel access mechanisms similar to those discussed above for NR-U need to be introduced for SL unlicensed operation (SL-U). For example, a SL UE may need to perform LBT before a SL transmission to another UE.

It also is desirable to re-use the NR-U UL/DL interlace technique for NR SL operation in unlicensed spectrum. At a high level, directly applying interlaces to SL is not possible because the minimum allocation unit in SL is a sub-channel and all SL procedures are defined in terms of sub-channels. However, various problems, issues, and/or difficulties arise when trying to adapt NR-U interlace techniques to the sub-channel structure of the SL resource pools.

For example, in unlicensed bands, there is typically an intra-cell (or inter-carrier) guard band between adjacent unlicensed channels, such as illustrated in Figure 5. It is unclear how to handle the additional RBs of the intra-cell guard band for interlaced SL transmissions. In some cases, these additional RBs may be assigned to a sub-channel that is smaller than other sub-channels. It is unclear how to handle varying sub-channel sizes for interlaced SL transmissions.

As another example, different UEs may support transmission/reception (TX/RX) on a different number of unlicensed channels. For example, some UEs may support TX/RX in all channels in an unlicensed band, while others may only support TX/RX in a subset of channels. Consequently, different UEs may be configured with different BWPs and resource pools that span different sets of RBs. It is unclear how to handle this UE-variable behavior and/or configuration for interlaced SL transmissions. For example, it may result in interlaces being defined in different ways for different users, which can increase interference in the unlicensed channel.

As another example, for unlicensed bands with multiple channels, the mapping of interlaces to channels (and sub-channels) may require large amount of configuration information. This can add significant complexity to signaling, in terms of both implementation and standardization.

Accordingly, embodiments of the present disclosure provide flexible and efficient techniques for mapping interlaces for transmission on unlicensed spectrum to sub-channels in SL resource pools, thereby facilitating use of SL interlaced transmission in unlicensed spectrum. At a high level, these techniques set the number of interlaces equal to the number of configured sub-channels and define each interlace by using a virtual mapping that spreads the sub-channel resources over frequency. Embodiments also provide techniques to deal with additional RBs that do not belong to a sub-channel or that belong to a sub-channel with a smaller size, as well as to ensure continuity in interlaces that cross adjacent resource pools (e.g., for different channels). In this manner, embodiments can extend a basic mapping (i.e., for a single channel) over a larger band (i.e., with multiple channels).

Embodiments provide various benefits and/or advantages. For example, mapping between sub-channel and interlace allows for reusing legacy procedures for SL resource allocation and transmission. As another example, interlaces are defined such that for a given channel, resources corresponding to an interlace do not change when that channel is combined with other channels for transmission. Put differently, for a particular sub-channel of an SL resource pool, the corresponding interlace contains the same RBs regardless of whether that is the only selected sub-channel or one of multiple selected sub-channels, and regardless of whether a single channel is used or multiple channels are used. Mapping between sub-channel and interlace is performed the same way for every UE transmitting in the unlicensed band.

As another example, since interlacing is treated as mapping from sub-channel to transmission resources, embodiments enable a SL UE, e.g., one of the UEs 810, 820, to operate according to the same principles independent of whether it uses interlacing. In other words, legacy SL procedures can be largely reused for unlicensed operation after including these novel mapping techniques.

Figure 12 shows an exemplary mapping for a 20-MHz channel arranged as a SL resource pool with Nsubch = 4 sub-channels, according to some embodiments of the present disclosure. The respective sub-channels are denoted with different shading and each includes Nrb = 4 contiguous RBs, as illustrated in the top part of Figure 12. The bottom part of Figure 12 shows how Ninterlaces = Nsubch = 4 are created by applying a mapping to distribute the RBs of each sub-channel to different interlaces, with successive RBs of each interlace spaced Nsubch = 4 RBs apart.

Figure 13 shows an exemplary mapping for a 20-MHz channel arranged as a SL resource pool with Nsubch = 3 sub-channels, according to other embodiments of the present disclosure.

The respective sub-channels are denoted with different shading and each includes Nrb = 4 contiguous RBs, as illustrated in the top part of Figure 13. The bottom part of Figure 13 shows how Ninterlaces = Nsubch = 3 are created by applying a mapping to distribute the RBs of each sub-channel to different interlaces, with successive RBs of each interlace spaced Nsubch = 3 RBs apart.

In some cases, the total number of RBs spanning the system bandwidth (e.g., resource pool width) can be larger than Nsubch * Nrb. These so-called additional RBs (which may be guard band) are not associated with any of the Nsubch sub-channels. For example, these additional RBs are found at one edge of the system bandwidth. Figure 5 shows another example where the additional RBs are distributed over the system bandwidth.

In some embodiments, the additional RBs can be assigned to interlaces following the mapping used for the sub-channels, until the additional RBs are exhausted. Figure 14 shows a 20-MHz channel arranged as a SL resource pool with Nsubch = 3 sub-channels, each with Nrb = 4 contiguous RBs, plus two additional RBs at channel edge. The two additional RBs are assigned to the first two interlaces (checked boxes and dotted boxes). Consequently, the first two interlaces (checked boxes and dotted boxes) consist of five RBs and the third interlace (grid box) consists of four RBs.

For the case of a larger bandwidth, such as shown in Figure 5, one straightforward approach is to repeat the mapping illustrated in Figure 14 over the larger bandwidth. Figure 15 shows a 40-MHz system bandwidth arranged as two 20-MHz channels arranged as two SL resource pools, each with Nsubch = 3 sub-channels, each with Nrb = 4 contiguous RBs. There are two additional RBs at edge of each channel. For both channels, the two additional RBs are assigned to the first two interlaces (checked boxes and dotted boxes). This approach has a drawback that the interlaces no longer have equally spaced RBs. Specifically, for each interlace, the RBs in the region where the two 20-MHz channels meet have a different separation than other RBs of the same interlace.

As an alternative approach, the additional RBs can be assigned to interlaces in a round-robin manner. Figure 16 illustrates this technique based on the same 40-MHz system bandwidth arrangement shown in Figure 15. The two additional RBs for the first channel are assigned to the first two interlaces (checked boxes and dotted boxes) as before. The two additional RBs for the second channel are assigned to the next two interlaces in order, i.e., the third and first interlaces. For a 60-MHz system bandwidth with an identical third channel, the two additional RBs for the third channel would be assigned to the next two interlaces in order, i.e., the second and third interlaces.

Although the additional RBs were described above as being part of a channel, they may alternately be part of both channels or part of neither channel (e.g., a guard band). This status does not affect the mapping of the additional RBs to interlaces. Conventionally, the additional RBs may only be used when a transmission spans the two adjacent channels (i.e., on either side of the additional RBs). In contrast, embodiments of the present disclosure map these additional RBs to interlaces that may also include RBs that are not adjacent to the additional RBs, such as illustrated in Figure 16.

When there are no additional RBs, the mapping from RBs in the sub-channel to RBs in the interlace is one-to-one. Since the legacy procedures define the contents of the RBs in the sub-channels, the contents of the RBs in the interlace is automatically defined. When there are additional RBs, some interlaces have more RBs that the corresponding sub-channel. In this case, it is necessary to define the contents of these RBs.

In some embodiments, the additional RBs include a repetition of the content of other RBs in the same interlace (e.g., preceding RB, next RB, etc.). Alternatively, one or more of the additional RBs in an interlace may be punctured or omitted when the interlace includes a maximum number of RBs per sub-channel or interlace, i.e., without the punctured RBs. For example, the maximum number can correspond to the contents to be transmitted, such that the additional RBs would be punctured if there is no contents to fill them.

In some embodiments, the additional RBs are treated like other RBs comprising the sub-channels, such that physical control channels (e.g., PSCCH), physical shared channels (e.g., PSSCH), reference signals, etc. are generated using the number of RBs in the interlace rather than the number of RBs in the sub-channel.

In some embodiments, the mapping between sub-channels and interlaces is defined over the entire width of a band that spans multiple channels, such as illustrated in Figures 15-16. In other embodiments, the mapping is defined over part of the band. For example, this would correspond to configuring the mapping for one of the two 20-MHz channels in Figures 15-16 (i.e., left or right).

In some embodiments, a combination of these types of mappings can be used. For example, a first UE may be able to TX/RX on all channels in the band, and is configured with a resource pool that defines a sub-channel-to-interlace mapping over the entire band. In contrast, a second UE may be able to TX/RX on a subset of the channels in the band (e.g., one channel), and is configured with a resource poll that defines a sub-channel-to-interlace mapping over the subset. However, the first and second UEs are configured with the same sub-channel-to-interlace mapping over the subset for the subset in which they both are able to TX/RX.

In some embodiments, instead of leaving additional RBs unused, a ssmaller sub-channel may be defined at the edge of a channel and/or resource pool). Figure 13 shows an exemplary mapping for a 20-MHz channel arranged as a SL resource pool with Nsubch = 3 sub-channels that span 10 RBs, according to these embodiments. Two sub-channels consist of $N_{RB} = 4$ consecutive resource blocks (RBs) each, denoted in checked/dotted boxes. The third sub-channel consists of $N_{RB} = 2$ consecutive resource blocks (RBs), in grided boxes. $N_{interlaces} = N_{subch} = 3$ interlaces are defined by the mapping shown in Figure 17. Each interlace includes the N_{RB} RBs from one sub-channel, but the interlaces have variably spaced RBs due to the variable number of RBs per sub-channel. Even so, the variation may be reduced compared to leaving additional RBs unused.

In some embodiments, mappings for multiple adjacent channels can be concatenated. Figure 18 shows a 40-MHz system bandwidth arranged as two 20-MHz channels arranged as two SL resource pools, according to some of these embodiments. Each channel includes Nsubch = 3 sub-channels that span 10 RBs, with two sub-channels consisting of $N_{RB} = 4$ consecutive RBs (denoted by checkered/dotted boxes) and the third sub-channel consisting of $N_{RB} = 2$ consecutive RBs (denoted by grided boxes). In these embodiments, the two first sub-channels (checkered) are mapped to a first interlace, the two second sub-channels (dotted) are mapped to a second interlace, and the two third sub-channels (gridded) are mapped to a third interlace.

Note that in Figure 18, the third sub-channel from each channel is only mapped in sequence with RBs from other sub-channels of the same channel (which can be referred to as a “direct mapping”). Figure 19 shows a variant in which the third sub-channel from each channel is mapped out of sequence with RBs from other sub-channels of the same channel (which can be referred to as an “offset mapping”). For example, the first RB from the third sub-channel of the second channel is mapped before the first RB of the first sub-channel of the second channel. Note the distance between consecutive RBs in an interlace is variable in both Figures 17-19 due the unequally-sized sub-channels, although the nature of the variations differ.

In some embodiments, once configured with a resource pool that has an associated sub-channel-to-interlace mapping, a UE selects one sub-channel and uses the mapping to determine the RBs of the interlace. For example, the UE can determine the RBs used to transmit based on the selected sub-channel and the mapping. As another example, the UE can determine the RBs to be used for a measurement or a sensing operation (e.g., LBT) based on the selected sub-channel and the mapping. As a more specific example, the UE performs measurements (e.g., RSRP) on the RBs of the corresponding interlace to assess whether a sub-channel is busy. If the UE determines that the sub-channel is busy or reserved (e.g., for a future transmission), then it determines that the RBs of the corresponding interlace are busy or reserved.

Various features of the embodiments described above correspond to various operations illustrated in Figures 20-21, which show exemplary methods (*e.g.*, procedures) for a UE and a RAN node, respectively. The UE could for example correspond to one of the UEs 810, 820 in any of the scenarios of Figure 8. The RAN node could correspond to the RAN node 830 of Figure 8. In other words, various features of the operations described below correspond to various embodiments described above. Furthermore, the exemplary methods shown in Figures 8-9 can be used cooperatively to provide various benefits, advantages, and/or solutions to problems described herein. Although Figures 8-9 show specific blocks in particular orders, the operations of the exemplary methods can be performed in different orders than shown and can be combined and/or divided into blocks having different functionality than shown. Optional blocks or operations are indicated by dashed lines.

In particular, Figure 20 shows an exemplary method (e.g., procedure) for a UE configured for wireless SL communication with one or more other UEs, according to various embodiments of the present disclosure. The exemplary method can be performed by a UE (*e.g.*, wireless device) such as described elsewhere herein.

The exemplary method can include the operations of block 2010, where the UE can determine a configuration for one or more SL resource pools corresponding to one or more channels. Here, one SL resource pool may correspond to a respective channel, multiple SL resource pools may correspond to one respective channel, or multiple SL resource pools may correspond to multiple respective channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels. As indicated by block 2011, determining the configuration may involve receiving the configuration from a RAN node. Alternatively or in addition, the configuration could at least in part be based on pre-configuration of the UE, e.g., based on data stored in a SIM of the UE, based on manufacturer settings, and/or based on requirements of a standard.

In some embodiments, the exemplary method can also include the operations of blocks 2020-2040. In blocks 820-830, where the UE can select a sub-channel from at least one SL resource pool that corresponds to at least one channel and determine RBs comprising a first one of the interlaced resource allocations based on the selected at least one sub-channel and the first mapping. In block 2040, the UE can perform wireless SL communication using the RBs comprising the first interlaced resource allocation. Performing the wireless SL communication may in particular involve transmitting on the RBs comprising the first interlaced resource allocation.

In some embodiments, performing wireless SL communication in block 2040 includes one or more of the following operations, denoted by corresponding sub-block numbers:

- (2041) performing radio measurements on the RBs comprising the first interlaced resource allocation;
- (2042) based on the radio measurements, determining whether the sub-channel corresponding to the first interlaced resource allocation is free, busy, or reserved, e.g., for a future transmission; and
- (2043) transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation.

In some embodiments, the configuration is for a single SL resource pool corresponding to a single channel and the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations. In other embodiments, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the first mapping is between a first plurality of sub-channels – in each of the SL resource pools – and a first plurality of interlaced resource allocations. Variants of both types of embodiments are described below.

In some of these embodiments, in each SL resource pool, each sub-channel includes a second plurality of RBs and each interlaced resource allocation comprises RBs that occur every first plurality of RBs. Figures 12-13 show some examples of these embodiments.

In other of these embodiments, in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs and the exception sub-channel includes less than the second plurality of RBs. In such case, each interlaced resource allocation comprises RBs that are variably spaced in frequency. Figures 17-19 show examples of these embodiments.

In some variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation. Figures 18-19 show examples of these variants. In some further variants, in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel and one of the following applies:

- the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool (e.g., as illustrated in Figure 18); or
- the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool (e.g., as illustrated in Figure 19).

In some of these embodiments, each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels and the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations. For example, each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

In some variants, in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel and for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel. Figures 14-15 show examples of these variants.

In other variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels. In each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel. The second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel, while the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool. Figure 16 shows an example of these variants.

In some of the above-described variants, transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation in block 2040 includes one of the following with respect to the additional RBs comprising the first interlaced resource allocation:

- transmitting, in the additional RBs, a repetition of data transmitted in the sub-channel RBs that are mapped to the first interlaced resource allocation; or
- refraining from transmitting in one or more of the additional RBs.

Some examples of these operations were discussed above.

In some embodiments, the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

- the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or
- the RBs comprising sub-channels of a subset of the plurality of channels (e.g., a single channel), and a subset of the plurality of interlaced resource allocations (e.g., a single allocation) that span the subset of the plurality of channels.

In addition, Figure 21 shows an exemplary method (e.g., procedure) for a RAN node configured to facilitate wireless SL communication between a plurality of UEs, according to various embodiments of the present disclosure. The exemplary method can be performed by a RAN node (*e.g.*, base station, eNB, gNB, ng-eNB, etc.) such as described elsewhere herein.

The exemplary method can include the operations of block 2110, where the RAN node can send, to a plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels. Here, one SL resource pool may correspond to a respective channel, multiple SL resource pools may correspond to one respective channel, or multiple SL resource pools may correspond to multiple respective channels. Each SL resource pool comprises a plurality of non-overlapping sub-channels. Each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency. The configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

In some embodiments, the configuration is for a single SL resource pool corresponding to a single channel and the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations. In other embodiments, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the first mapping is between a first plurality of sub-channels – in each of the SL resource pools – and a first plurality of interlaced resource allocations. Variants of both types of embodiments are described below.

In some of these embodiments, in each SL resource pool, each sub-channel includes a second plurality of RBs and each interlaced resource allocation comprises RBs that occur every first plurality of RBs. Figures 12-13 show some examples of these embodiments.

In other of these embodiments, in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs and the exception sub-channel includes less than the second plurality of RBs. In such case, each interlaced resource allocation comprises RBs that are variably spaced in frequency. Figures 17-19 show examples of these embodiments.

In some variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels and the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation. Figures 18-19 show examples of these variants. In some further variants, in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel and one of the following applies:

- the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool (e.g., as illustrated in Figure 18); or

- the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool (e.g., as illustrated in Figure 19).

In some of these embodiments, each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels and the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations. For example, each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

In some variants, in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel and for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel. Figures 14-15 show examples of these variants.

In other variants, the configuration is for a plurality of SL resource pools corresponding to a plurality of channels. In each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel. The second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel, while the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool. Figure 16 shows an example of these variants.

In some embodiments, the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

- the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or
- the RBs comprising sub-channels of a subset of the plurality of channels (e.g., a single channel), and a subset of the plurality of interlaced resource allocations (e.g., a single allocation) that span the subset of the plurality of channels.

In some embodiments, the configuration sent to a first UE is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the configuration sent to a second UE includes is for a subset of the plurality of SL resource pools corresponding to a respective subset of the plurality of channels.

Although various embodiments are described above in terms of methods, techniques, and/or procedures, the person of ordinary skill will readily comprehend that such methods, techniques, and/or procedures can be embodied by various combinations of hardware and software in various systems, communication devices, computing devices, control devices, apparatuses, non-transitory computer-readable media, computer program products, *etc.*

Figure 22 shows an example of a communication system 2200 in accordance with some embodiments. In this example, the communication system 2200 includes a telecommunication network 2202 that includes an access network 2204, such as a radio access network (RAN), and a core network 2206, which includes one or more core network nodes 2208. The access network 2204 includes one or more access network nodes, such as network nodes 2210a and 2210b (one or more of which may be generally referred to as network nodes 2210), or any other similar 3rd Generation Partnership Project (3GPP) access node or non-3GPP access point. The network nodes 2210 facilitate direct or indirect connection of user equipment (UE), such as by connecting UEs 2212a, 2212b, 2212c, and 2212d (one or more of which may be generally referred to as UEs 2212) to the core network 2206 over one or more wireless connections.

Example wireless communications over a wireless connection include transmitting and/or receiving wireless signals using electromagnetic waves, radio waves, infrared waves, and/or other types of signals suitable for conveying information without the use of wires, cables, or other material conductors. Moreover, in different embodiments, the communication system 2200 may include any number of wired or wireless networks, network nodes, UEs, and/or any other components or systems that may facilitate or participate in the communication of data and/or signals whether via wired or wireless connections. The communication system 2200 may include and/or interface with any type of communication, telecommunication, data, cellular, radio network, and/or other similar type of system.

The UEs 2212 may be any of a wide variety of communication devices, including wireless devices arranged, configured, and/or operable to communicate wirelessly with the network nodes 2210 and other communication devices. Similarly, the network nodes 2210 are arranged, capable, configured, and/or operable to communicate directly or indirectly with the UEs 2212 and/or with other network nodes or equipment in the telecommunication network 2202 to enable and/or provide network access, such as wireless network access, and/or to perform other functions, such as administration in the telecommunication network 2202. As illustrated by way of example for UEs 2212a and 2212b, the UEs may also perform direct SL communication. Such SL communication may be based on the concepts of the present disclosure. For example, the UE 2212a or the UE 2212b could operate according to the method of Figure 20, and such operation could be assisted by the network node 2210a or the network node 2210b by providing configuration information. For this purpose, the network node 2210a or the network node 2210b could operate according to the method of Figure 21.

In the depicted example, the core network 2206 connects the network nodes 2210 to one or more hosts, such as host 2216. These connections may be direct or indirect via one or more intermediary networks or devices. In other examples, network nodes may be directly coupled to hosts. The core network 2206 includes one more core network nodes (e.g., core network node 2208) that are structured with hardware and software components. Features of these components may be substantially similar to those described with respect to the UEs, network nodes, and/or hosts, such that the descriptions thereof are generally applicable to the corresponding components of the core network node 2208. Example core network nodes include functions of one or more of a Mobile Switching Center (MSC), Mobility Management Entity (MME), Home Subscriber Server (HSS), Access and Mobility Management Function (AMF), Session Management Function (SMF), Authentication Server Function (AUSF), Subscription Identifier De-concealing function (SIDF), Unified Data Management (UDM), Security Edge Protection Proxy (SEPP), Network Exposure Function (NEF), and/or a User Plane Function (UPF).

The host 2216 may be under the ownership or control of a service provider other than an operator or provider of the access network 2204 and/or the telecommunication network 2202, and may be operated by the service provider or on behalf of the service provider. The host 2216 may host a variety of applications to provide one or more service. Examples of such applications include live and pre-recorded audio/video content, data collection services such as retrieving and compiling data on various ambient conditions detected by a plurality of UEs, analytics functionality, social media, functions for controlling or otherwise interacting with remote devices, functions for an alarm and surveillance center, or any other such function performed by a server.

As a whole, the communication system 2200 of Figure 22 enables connectivity between the UEs, network nodes, and hosts. In that sense, the communication system may be configured to operate according to predefined rules or procedures, such as specific standards that include, but are not limited to: Global System for Mobile Communications (GSM); Universal Mobile Telecommunications System (UMTS); Long Term Evolution (LTE), and/or other suitable 2G, 3G, 4G, 5G standards, or any applicable future generation standard (e.g., 6G); wireless local area network (WLAN) standards, such as the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards (WiFi); and/or any other appropriate wireless communication standard, such as the Worldwide Interoperability for Microwave Access (WiMax), Bluetooth, Z-Wave, Near Field Communication (NFC) ZigBee, LiFi, and/or any low-power wide-area network (LPWAN) standards such as LoRa and Sigfox.

In some examples, the telecommunication network 2202 is a cellular network that implements 3GPP standardized features. Accordingly, the telecommunications network 2202 may support network slicing to provide different logical networks to different devices that are connected to the telecommunication network 2202. For example, the telecommunications network 2202 may provide Ultra Reliable Low Latency Communication (URLLC) services to some UEs, while providing Enhanced Mobile Broadband (eMBB) services to other UEs, and/or Massive Machine Type Communication (mMTC)/Massive IoT services to yet further UEs.

In some examples, the UEs 2212 are configured to transmit and/or receive information without direct human interaction. For instance, a UE may be designed to transmit information to the access network 2204 on a predetermined schedule, when triggered by an internal or external event, or in response to requests from the access network 2204. Additionally, a UE may be configured for operating in single- or multi-RAT or multi-standard mode. For example, a UE may operate with any one or combination of Wi-Fi, NR (New Radio) and LTE, i.e., being configured for multi-radio dual connectivity (MR-DC), such as E-UTRAN (Evolved-UMTS Terrestrial Radio Access Network) New Radio – Dual Connectivity (EN-DC).

In the example, the hub 2214 communicates with the access network 2204 to facilitate indirect communication between one or more UEs (e.g., UE 2212c and/or 2212d) and network nodes (e.g., network node 2210b). In some examples, the hub 2214 may be a controller, router, content source and analytics, or any of the other communication devices described herein regarding UEs. For example, the hub 2214 may be a broadband router enabling access to the core network 2206 for the UEs. As another example, the hub 2214 may be a controller that sends commands or instructions to one or more actuators in the UEs. Commands or instructions may be received from the UEs, network nodes 2210, or by executable code, script, process, or other instructions in the hub 2214. As another example, the hub 2214 may be a data collector that acts as temporary storage for UE data and, in some embodiments, may perform analysis or other processing of the data. As another example, the hub 2214 may be a content source. For example, for a UE that is a VR headset, display, loudspeaker or other media delivery device, the hub 2214 may retrieve VR assets, video, audio, or other media or data related to sensory information via a network node, which the hub 2214 then provides to the UE either directly, after performing local processing, and/or after adding additional local content. In still another example, the hub 2214 acts as a proxy server or orchestrator for the UEs, in particular in if one or more of the UEs are low energy IoT devices.

The hub 2214 may have a constant/persistent or intermittent connection to the network node 2210b. The hub 2214 may also allow for a different communication scheme and/or schedule between the hub 2214 and UEs (e.g., UE 2212c and/or 2212d), and between the hub 2214 and the core network 2206. In other examples, the hub 2214 is connected to the core network 2206 and/or one or more UEs via a wired connection. Moreover, the hub 2214 may be configured to connect to an M2M service provider over the access network 2204 and/or to another UE over a direct connection. In some scenarios, UEs may establish a wireless connection with the network nodes 2210 while still connected via the hub 2214 via a wired or wireless connection. In some embodiments, the hub 2214 may be a dedicated hub – that is, a hub whose primary function is to route communications to/from the UEs from/to the network node 2210b. In other embodiments, the hub 2214 may be a non-dedicated hub – that is, a device which is capable of operating to route communications between the UEs and network node 2210b, but which is additionally capable of operating as a communication start and/or end point for certain data channels.

Figure 23 shows a UE 2300 in accordance with some embodiments. As used herein, a UE refers to a device capable, configured, arranged and/or operable to communicate wirelessly with network nodes and/or other UEs. Examples of a UE include, but are not limited to, a smart phone, mobile phone, cell phone, voice over IP (VoIP) phone, wireless local loop phone, desktop computer, personal digital assistant (PDA), wireless cameras, gaming console or device, music storage device, playback appliance, wearable terminal device, wireless endpoint, mobile station, tablet, laptop, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), smart device, wireless customer-premise equipment (CPE), vehicle-mounted or vehicle embedded/integrated wireless device, etc. Other examples include any UE identified by the 3rd Generation Partnership Project (3GPP), including a narrow band internet of things (NB-IoT) UE, a machine type communication (MTC) UE, and/or an enhanced MTC (eMTC) UE.

A UE may support device-to-device (D2D) communication, for example by implementing a 3GPP standard for sidelink communication, Dedicated Short-Range Communication (DSRC), vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), or vehicle-to-everything (V2X). In the context of the present disclosure, the UE 2300 could perform SL communication with one or more other UEs, and for this purpose operate according to the method of Figure 20. In other examples, a UE may not necessarily have a user in the sense of a human user who owns and/or operates the relevant device. Instead, a UE may represent a device that is intended for sale to, or operation by, a human user but which may not, or which may not initially, be associated with a specific human user (e.g., a smart sprinkler controller). Alternatively, a UE may represent a device that is not intended for sale to, or operation by, an end user but which may be associated with or operated for the benefit of a user (e.g., a smart power meter).

The UE 2300 includes processing circuitry 2302 that is operatively coupled via a bus 2304 to an input/output interface 2306, a power source 2308, a memory 2310, a communication interface 2312, and/or any other component, or any combination thereof. Certain UEs may utilize all or a subset of the components shown in Figure 23. The level of integration between the components may vary from one UE to another UE. Further, certain UEs may contain multiple instances of a component, such as multiple processors, memories, transceivers, transmitters, receivers, etc.

The processing circuitry 2302 is configured to process instructions and data and may be configured to implement any sequential state machine operative to execute instructions stored as machine-readable computer programs in the memory 2310. The processing circuitry 2302 may be implemented as one or more hardware-implemented state machines (e.g., in discrete logic, field-programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), etc.); programmable logic together with appropriate firmware; one or more stored computer programs, general-purpose processors, such as a microprocessor or digital signal processor (DSP), together with appropriate software; or any combination of the above. For example, the processing circuitry 2302 may include multiple central processing units (CPUs).

In the example, the input/output interface 2306 may be configured to provide an interface or interfaces to an input device, output device, or one or more input and/or output devices. Examples of an output device include a speaker, a sound card, a video card, a display, a monitor, a printer, an actuator, an emitter, a smartcard, another output device, or any combination thereof. An input device may allow a user to capture information into the UE 2300. Examples of an input device include a touch-sensitive or presence-sensitive display, a camera (e.g., a digital camera, a digital video camera, a web camera, etc.), a microphone, a sensor, a mouse, a trackball, a directional pad, a trackpad, a scroll wheel, a smartcard, and the like. The presence-sensitive display may include a capacitive or resistive touch sensor to sense input from a user. A sensor may be, for instance, an accelerometer, a gyroscope, a tilt sensor, a force sensor, a magnetometer, an optical sensor, a proximity sensor, a biometric sensor, etc., or any combination thereof. An output device may use the same type of interface port as an input device. For example, a Universal Serial Bus (USB) port may be used to provide an input device and an output device.

In some embodiments, the power source 2308 is structured as a battery or battery pack. Other types of power sources, such as an external power source (e.g., an electricity outlet), photovoltaic device, or power cell, may be used. The power source 2308 may further include power circuitry for delivering power from the power source 2308 itself, and/or an external power source, to the various parts of the UE 2300 via input circuitry or an interface such as an electrical power cable. Delivering power may be, for example, for charging of the power source 2308. Power circuitry may perform any formatting, converting, or other modification to the power from the power source 2308 to make the power suitable for the respective components of the UE 2300 to which power is supplied.

The memory 2310 may be or be configured to include memory such as random access memory (RAM), read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable programmable read-only memory (EEPROM), magnetic disks, optical disks, hard disks, removable cartridges, flash drives, and so forth. In one example, the memory 2310 includes one or more application programs 2314, such as an operating system, web browser application, a widget, gadget engine, or other application, and corresponding data 2316. The memory 2310 may store, for use by the UE 2300, any of a variety of various operating systems or combinations of operating systems.

The memory 2310 may be configured to include a number of physical drive units, such as redundant array of independent disks (RAID), flash memory, USB flash drive, external hard disk drive, thumb drive, pen drive, key drive, high-density digital versatile disc (HD-DVD) optical disc drive, internal hard disk drive, Blu-Ray optical disc drive, holographic digital data storage (HDDS) optical disc drive, external mini-dual in-line memory module (DIMM), synchronous dynamic random access memory (SDRAM), external micro-DIMM SDRAM, smartcard memory such as tamper resistant module in the form of a universal integrated circuit card (UICC) including one or more subscriber identity modules (SIMs), such as a USIM and/or ISIM, other memory, or any combination thereof. The UICC may for example be an embedded UICC (eUICC), integrated UICC (iUICC) or a removable UICC commonly known as 'SIM card.' The memory 2310 may allow the UE 2300 to access instructions, application programs and the like, stored on transitory or non-transitory memory media, to off-load data, or to upload data. An article of manufacture, such as one utilizing a communication system may be tangibly embodied as or in the memory 2310, which may be or comprise a device-readable storage medium.

The processing circuitry 2302 may be configured to communicate with an access network or other network using the communication interface 2312. The communication interface 2312 may comprise one or more communication subsystems and may include or be communicatively coupled to an antenna 2322. The communication interface 2312 may include one or more transceivers used to communicate, such as by communicating with one or more remote transceivers of another device capable of wireless communication (e.g., another UE or a network node in an access network). Each transceiver may include a transmitter 2318 and/or a receiver 2320 appropriate to provide network communications (e.g., optical, electrical, frequency allocations, and so forth). Moreover, the transmitter 2318 and receiver 2320 may be coupled to one or more antennas (e.g., antenna 2322) and may share circuit components, software or firmware, or alternatively be implemented separately.

In the illustrated embodiment, communication functions of the communication interface 2312 may include cellular communication, Wi-Fi communication, LPWAN communication, data communication, voice communication, multimedia communication, short-range communications such as Bluetooth, near-field communication, location-based communication such as the use of the global positioning system (GPS) to determine a location, another like communication function, or any combination thereof. Communications may be implemented in according to one or more communication protocols and/or standards, such as IEEE 802.11, Code Division Multiplexing Access (CDMA), Wideband Code Division Multiple Access (WCDMA), GSM, LTE, New Radio (NR), UMTS, WiMax, Ethernet, transmission control protocol/internet protocol (TCP/IP), synchronous optical networking (SONET), Asynchronous Transfer Mode (ATM), QUIC, Hypertext Transfer Protocol (HTTP), and so forth.

Regardless of the type of sensor, a UE may provide an output of data captured by its sensors, through its communication interface 2312, via a wireless connection to a network node. Data captured by sensors of a UE can be communicated through a wireless connection to a network node via another UE. The output may be periodic (e.g., once every 15 minutes if it reports the sensed temperature), random (e.g., to even out the load from reporting from several sensors), in response to a triggering event (e.g., an alert is sent when moisture is detected), in response to a request (e.g., a user initiated request), or a continuous stream (e.g., a live video feed of a patient).

As another example, a UE comprises an actuator, a motor, or a switch, related to a communication interface configured to receive wireless input from a network node via a wireless connection. In response to the received wireless input the states of the actuator, the motor, or the switch may change. For example, the UE may comprise a motor that adjusts the control surfaces or rotors of a drone in flight according to the received input or to a robotic arm performing a medical procedure according to the received input.

A UE, when in the form of an Internet of Things (IoT) device, may be a device for use in one or more application domains, these domains comprising, but not limited to, city wearable technology, extended industrial application and healthcare. Non-limiting examples of such an IoT device are a device which is or which is embedded in: a connected refrigerator or freezer, a TV, a connected lighting device, an electricity meter, a robot vacuum cleaner, a voice controlled smart speaker, a home security camera, a motion detector, a thermostat, a smoke detector, a door/window sensor, a flood/moisture sensor, an electrical door lock, a connected doorbell, an air conditioning system like a heat pump, an autonomous vehicle, a surveillance system, a weather monitoring device, a vehicle parking monitoring device, an electric vehicle charging station, a smart watch, a fitness tracker, a head-mounted display for Augmented Reality (AR) or Virtual Reality (VR), a wearable for tactile augmentation or sensory enhancement, a water sprinkler, an animal- or item-tracking device, a sensor for monitoring a plant or animal, an industrial robot, an Unmanned Aerial Vehicle (UAV), and any kind of medical device, like a heart rate monitor or a remote controlled surgical robot. A UE in the form of an IoT device comprises circuitry and/or software in dependence of the intended application of the IoT device in addition to other components as described in relation to the UE 2300 shown in Figure 23.

As yet another specific example, in an IoT scenario, a UE may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another UE and/or a network node. The UE may in this case be an M2M device, which may in a 3GPP context be referred to as an MTC device. As one particular example, the UE may implement the 3GPP NB-IoT standard. In other scenarios, a UE may represent a vehicle, such as a car, a bus, a truck, a ship and an airplane, or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation.

In practice, any number of UEs may be used together with respect to a single use case. For example, a first UE might be or be integrated in a drone and provide the drone's speed information (obtained through a speed sensor) to a second UE that is a remote controller operating the drone. When the user makes changes from the remote controller, the first UE may adjust the throttle on the drone (e.g., by controlling an actuator) to increase or decrease the drone's speed. The first and/or the second UE can also include more than one of the functionalities described above. For example, a UE might comprise the sensor and the actuator, and handle communication of data for both the speed sensor and the actuators.

Figure 24 shows a network node 2400 in accordance with some embodiments. As used herein, network node refers to equipment capable, configured, arranged and/or operable to communicate directly or indirectly with a UE and/or with other network nodes or equipment, in a telecommunication network. Examples of network nodes include, but are not limited to, access points (APs) (e.g., radio access points), base stations (BSs) (e.g., radio base stations, Node Bs, evolved Node Bs (eNBs) and NR NodeBs (gNBs)). In the context of the present disclosure, the network node 2400 could facilitate SL communication between UEs by providing configuration information to at least one of the UEs. For this purpose, the network node 2400 could operate according to the method of Figure 20.

Base stations may be categorized based on the amount of coverage they provide (or, stated differently, their transmit power level) and so, depending on the provided amount of coverage, may be referred to as femto base stations, pico base stations, micro base stations, or macro base stations. A base station may be a relay node or a relay donor node controlling a relay. A network node may also include one or more (or all) parts of a distributed radio base station such as centralized digital units and/or remote radio units (RRUs), sometimes referred to as Remote Radio Heads (RRHs). Such remote radio units may or may not be integrated with an antenna as an antenna integrated radio. Parts of a distributed radio base station may also be referred to as nodes in a distributed antenna system (DAS).

Other examples of network nodes include multiple transmission point (multi-TRP) 5G access nodes, multi-standard radio (MSR) equipment such as MSR BSs, network controllers such as radio network controllers (RNCs) or base station controllers (BSCs), base transceiver stations (BTSs), transmission points, transmission nodes, multi-cell/multicast coordination entities (MCEs), Operation and Maintenance (O&M) nodes, Operations Support System (OSS) nodes, Self-Organizing Network (SON) nodes, positioning nodes (e.g., Evolved Serving Mobile Location Centers (E-SMLCs)), and/or Minimization of Drive Tests (MDTs).

The network node 2400 includes a processing circuitry 2402, a memory 2404, a communication interface 2406, and a power source 2408. The network node 2400 may be composed of multiple physically separate components (e.g., a NodeB component and a RNC component, or a BTS component and a BSC component, etc.), which may each have their own respective components. In certain scenarios in which the network node 2400 comprises multiple separate components (e.g., BTS and BSC components), one or more of the separate components may be shared among several network nodes. For example, a single RNC may control multiple NodeBs. In such a scenario, each unique NodeB and RNC pair, may in some instances be considered a single separate network node. In some embodiments, the network node 2400 may be configured to support multiple radio access technologies (RATs). In such embodiments, some components may be duplicated (e.g., separate memory 2404 for different RATs) and some components may be reused (e.g., a same antenna 2410 may be shared by different RATs). The network node 2400 may also include multiple sets of the various illustrated components for different wireless technologies integrated into network node 2400, for example GSM, WCDMA, LTE, NR, WiFi, Zigbee, Z-wave, LoRaWAN, Radio Frequency Identification (RFID) or Bluetooth wireless technologies. These wireless technologies may be integrated into the same or different chip or set of chips and other components within network node 2400.

The processing circuitry 2402 may comprise a combination of one or more of a microprocessor, controller, microcontroller, central processing unit, digital signal processor, application-specific integrated circuit, field programmable gate array, or any other suitable computing device, resource, or combination of hardware, software and/or encoded logic operable to provide, either alone or in conjunction with other network node 2400 components, such as the memory 2404, to provide network node 2400 functionality.

In some embodiments, the processing circuitry 2402 includes a system on a chip (SOC). In some embodiments, the processing circuitry 2402 includes one or more of radio frequency (RF) transceiver circuitry 2412 and baseband processing circuitry 2414. In some embodiments, the radio frequency (RF) transceiver circuitry 2412 and the baseband processing circuitry 2414 may be on separate chips (or sets of chips), boards, or units, such as radio units and digital units. In alternative embodiments, part or all of RF transceiver circuitry 2412 and baseband processing circuitry 2414 may be on the same chip or set of chips, boards, or units.

The memory 2404 may comprise any form of volatile or non-volatile computer-readable memory including, without limitation, persistent storage, solid-state memory, remotely mounted memory, magnetic media, optical media, random access memory (RAM), read-only memory (ROM), mass storage media (for example, a hard disk), removable storage media (for example, a flash drive, a Compact Disk (CD) or a Digital Video Disk (DVD)), and/or any other volatile or non-volatile, non-transitory device-readable and/or computer-executable memory devices that store information, data, and/or instructions that may be used by the processing circuitry 2402. The memory 2404 may store any suitable instructions, data, or information, including a computer program, software, an application including one or more of logic, rules, code, tables, and/or other instructions capable of being executed by the processing circuitry 2402 and utilized by the network node 2400. The memory 2404 may be used to store any calculations made by the processing circuitry 2402 and/or any data received via the communication interface 2406. In some embodiments, the processing circuitry 2402 and memory 2404 is integrated.

The communication interface 2406 is used in wired or wireless communication of signaling and/or data between a network node, access network, and/or UE. As illustrated, the communication interface 2406 comprises port(s)/terminal(s) 2416 to send and receive data, for example to and from a network over a wired connection. The communication interface 2406 also includes radio front-end circuitry 2418 that may be coupled to, or in certain embodiments a part of, the antenna 2410. Radio front-end circuitry 2418 comprises filters 2420 and amplifiers 2422. The radio front-end circuitry 2418 may be connected to an antenna 2410 and processing circuitry 2402. The radio front-end circuitry may be configured to condition signals communicated between antenna 2410 and processing circuitry 2402. The radio front-end circuitry 2418 may receive digital data that is to be sent out to other network nodes or UEs via a wireless connection. The radio front-end circuitry 2418 may convert the digital data into a radio signal having the appropriate channel and bandwidth parameters using a combination of filters 2420 and/or amplifiers 2422. The radio signal may then be transmitted via the antenna 2410. Similarly, when receiving data, the antenna 2410 may collect radio signals which are then converted into digital data by the radio front-end circuitry 2418. The digital data may be passed to the processing circuitry 2402. In other embodiments, the communication interface may comprise different components and/or different combinations of components.

In certain alternative embodiments, the network node 2400 does not include separate radio front-end circuitry 2418, instead, the processing circuitry 2402 includes radio front-end circuitry and is connected to the antenna 2410. Similarly, in some embodiments, all or some of the RF transceiver circuitry 2412 is part of the communication interface 2406. In still other embodiments, the communication interface 2406 includes one or more ports or terminals 2416, the radio front-end circuitry 2418, and the RF transceiver circuitry 2412, as part of a radio unit (not shown), and the communication interface 2406 communicates with the baseband processing circuitry 2414, which is part of a digital unit (not shown).

The antenna 2410 may include one or more antennas, or antenna arrays, configured to send and/or receive wireless signals. The antenna 2410 may be coupled to the radio front-end circuitry 2418 and may be any type of antenna capable of transmitting and receiving data and/or signals wirelessly. In certain embodiments, the antenna 2410 is separate from the network node 2400 and connectable to the network node 2400 through an interface or port.

The antenna 2410, communication interface 2406, and/or the processing circuitry 2402 may be configured to perform any receiving operations and/or certain obtaining operations described herein as being performed by the network node. Any information, data and/or signals may be received from a UE, another network node and/or any other network equipment. Similarly, the antenna 2410, the communication interface 2406, and/or the processing circuitry 2402 may be configured to perform any transmitting operations described herein as being performed by the network node. Any information, data and/or signals may be transmitted to a UE, another network node and/or any other network equipment.

The power source 2408 provides power to the various components of network node 2400 in a form suitable for the respective components (e.g., at a voltage and current level needed for each respective component). The power source 2408 may further comprise, or be coupled to, power management circuitry to supply the components of the network node 2400 with power for performing the functionality described herein. For example, the network node 2400 may be connectable to an external power source (e.g., the power grid, an electricity outlet) via an input circuitry or interface such as an electrical cable, whereby the external power source supplies power to power circuitry of the power source 2408. As a further example, the power source 2408 may comprise a source of power in the form of a battery or battery pack which is connected to, or integrated in, power circuitry. The battery may provide backup power should the external power source fail.

Embodiments of the network node 2400 may include additional components beyond those shown in Figure 24 for providing certain aspects of the network node’s functionality, including any of the functionality described herein and/or any functionality necessary to support the subject matter described herein. For example, the network node 2400 may include user interface equipment to allow input of information into the network node 2400 and to allow output of information from the network node 2400. This may allow a user to perform diagnostic, maintenance, repair, and other administrative functions for the network node 2400.

Figure 25 is a block diagram of a host 2500, which may be an embodiment of the host 2216 of Figure 22, in accordance with various aspects described herein. As used herein, the host 2500 may be or comprise various combinations hardware and/or software, including a standalone server, a blade server, a cloud-implemented server, a distributed server, a virtual machine, container, or processing resources in a server farm. The host 2500 may provide one or more services to one or more UEs.

The host 2500 includes processing circuitry 2502 that is operatively coupled via a bus 2504 to an input/output interface 2506, a network interface 2508, a power source 2510, and a memory 2512. Other components may be included in other embodiments. Features of these components may be substantially similar to those described with respect to the devices of previous figures, such as Figures 23 and 24, such that the descriptions thereof are generally applicable to the corresponding components of host 2500.

The memory 2512 may include one or more computer programs including one or more host application programs 2514 and data 2516, which may include user data, e.g., data generated by a UE for the host 2500 or data generated by the host 2500 for a UE. Embodiments of the host 2500 may utilize only a subset or all of the components shown. The host application programs 2514 may be implemented in a container-based architecture and may provide support for video codecs (e.g., Versatile Video Coding (VVC), High Efficiency Video Coding (HEVC), Advanced Video Coding (AVC), MPEG, VP9) and audio codecs (e.g., FLAC, Advanced Audio Coding (AAC), MPEG, G.711), including transcoding for multiple different classes, types, or implementations of UEs (e.g., handsets, desktop computers, wearable display systems, heads-up display systems). The host application programs 2514 may also provide for user authentication and licensing checks and may periodically report health, routes, and content availability to a central node, such as a device in or on the edge of a core network. Accordingly, the host 2500 may select and/or indicate a different host for over-the-top services for a UE. The host application programs 2514 may support various protocols, such as the HTTP Live Streaming (HLS) protocol, Real-Time Messaging Protocol (RTMP), Real-Time Streaming Protocol (RTSP), Dynamic Adaptive Streaming over HTTP (MPEG-DASH), etc.

Figure 26 is a block diagram illustrating a virtualization environment 2600 in which functions implemented by some embodiments may be virtualized. In the present context, virtualizing means creating virtual versions of apparatuses or devices which may include virtualizing hardware platforms, storage devices and networking resources. As used herein, virtualization can be applied to any device described herein, or components thereof, and relates to an implementation in which at least a portion of the functionality is implemented as one or more virtual components. Some or all of the functions described herein may be implemented as virtual components executed by one or more virtual machines (VMs) implemented in one or more virtual environments 2600 hosted by one or more of hardware nodes, such as a hardware computing device that operates as a network node, UE, core network node, or host. Further, in embodiments in which the virtual node does not require radio connectivity (e.g., a core network node or host), then the node may be entirely virtualized.

Applications 2602 (which may alternatively be called software instances, virtual appliances, network functions, virtual nodes, virtual network functions, etc.) are run in the virtualization environment 2500 to implement some of the features, functions, and/or benefits of some of the embodiments disclosed herein.

Hardware 2604 includes processing circuitry, memory that stores software and/or instructions executable by hardware processing circuitry, and/or other hardware devices as described herein, such as a network interface, input/output interface, and so forth. Software may be executed by the processing circuitry to instantiate one or more virtualization layers 2606 (also referred to as hypervisors or virtual machine monitors (VMMs)), provide VMs 2608a and 2608b (one or more of which may be generally referred to as VMs 2608), and/or perform any of the functions, features and/or benefits described in relation with some embodiments described herein. The virtualization layer 2606 may present a virtual operating platform that appears like networking hardware to the VMs 2608.

The VMs 2608 comprise virtual processing, virtual memory, virtual networking or interface and virtual storage, and may be run by a corresponding virtualization layer 2606. Different embodiments of the instance of a virtual appliance 2602 may be implemented on one or more of VMs 2608, and the implementations may be made in different ways. Virtualization of the hardware is in some contexts referred to as network function virtualization (NFV). NFV may be used to consolidate many network equipment types onto industry standard high volume server hardware, physical switches, and physical storage, which can be located in data centers, and customer premise equipment.

In the context of NFV, a VM 2608 may be a software implementation of a physical machine that runs programs as if they were executing on a physical, non-virtualized machine. Each of the VMs 2608, and that part of hardware 2604 that executes that VM, be it hardware dedicated to that VM and/or hardware shared by that VM with others of the VMs, forms separate virtual network elements. Still in the context of NFV, a virtual network function is responsible for handling specific network functions that run in one or more VMs 2608 on top of the hardware 2604 and corresponds to the application 2602.

Hardware 2604 may be implemented in a standalone network node with generic or specific components. Hardware 2604 may implement some functions via virtualization. Alternatively, hardware 2604 may be part of a larger cluster of hardware (e.g., such as in a data center or CPE) where many hardware nodes work together and are managed via management and orchestration 2610, which, among others, oversees lifecycle management of applications 2602. In some embodiments, hardware 2604 is coupled to one or more radio units that each include one or more transmitters and one or more receivers that may be coupled to one or more antennas. Radio units may communicate directly with other hardware nodes via one or more appropriate network interfaces and may be used in combination with the virtual components to provide a virtual node with radio capabilities, such as a radio access node or a base station. In some embodiments, some signaling can be provided with the use of a control system 2612 which may alternatively be used for communication between hardware nodes and radio units.

Figure 27 shows a communication diagram of a host 2702 communicating via a network node 2704 with a UE 2706 over a partially wireless connection in accordance with some embodiments. Example implementations, in accordance with various embodiments, of the UE (such as a UE 2212a of Figure 22 and/or UE 2300 of Figure 23), network node (such as network node 2210a of Figure 22 and/or network node 2400 of Figure 24), and host (such as host 2216 of Figure 22 and/or host 2500 of Figure 25) discussed in the preceding paragraphs will now be described with reference to Figure 27.

Like host 2500, embodiments of host 2702 include hardware, such as a communication interface, processing circuitry, and memory. The host 2702 also includes software, which is stored in or accessible by the host 2702 and executable by the processing circuitry. The software includes a host application that may be operable to provide a service to a remote user, such as the UE 2706 connecting via an over-the-top (OTT) connection 2750 extending between the UE 2706 and host 2702. In providing the service to the remote user, a host application may provide user data which is transmitted using the OTT connection 2750.

The network node 2704 includes hardware enabling it to communicate with the host 2702 and UE 2706. The connection 2760 may be direct or pass through a core network (like core network 2206 of Figure 22) and/or one or more other intermediate networks, such as one or more public, private, or hosted networks. For example, an intermediate network may be a backbone network or the Internet.

The UE 2706 includes hardware and software, which is stored in or accessible by UE 2706 and executable by the UE's processing circuitry. The software includes a client application, such as a web browser or operator-specific "app" that may be operable to provide a service to a human or non-human user via UE 2706 with the support of the host 2702. In the host 2702, an executing host application may communicate with the executing client application via the OTT connection 2750 terminating at the UE 2706 and host 2702. In providing the service to the user, the UE's client application may receive request data from the host's host application and provide user data in response to the request data. The OTT connection 2750 may transfer both the request data and the user data. The UE's client application may interact with the user to generate the user data that it provides to the host application through the OTT connection 2750.

The OTT connection 2750 may extend via a connection 2760 between the host 2702 and the network node 2704 and via a wireless connection 2770 between the network node 2704 and the UE 2706 to provide the connection between the host 2702 and the UE 2706. The connection 2760 and wireless connection 2770, over which the OTT connection 2750 may be provided, have been drawn abstractly to illustrate the communication between the host 2702 and the UE 2706 via the network node 2704, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Here, it is noted that in the context of the present disclosure the OTT connection may also extend via a SL connection between two UEs, such as illustrated in Figure 22 between UEs 2212a and 2212b.

As an example of transmitting data via the OTT connection 2750, in step 2708, the host 2702 provides user data, which may be performed by executing a host application. In some embodiments, the user data is associated with a particular human user interacting with the UE 2706. In other embodiments, the user data is associated with a UE 2706 that shares data with the host 2702 without explicit human interaction. In step 2710, the host 2702 initiates a transmission carrying the user data towards the UE 2706. The host 2702 may initiate the transmission responsive to a request transmitted by the UE 2706. The request may be caused by human interaction with the UE 2706 or by operation of the client application executing on the UE 2706. The transmission may pass via the network node 2704, in accordance with the teachings of the embodiments described throughout this disclosure. Accordingly, in step 2712, the network node 2704 transmits to the UE 2706 the user data that was carried in the transmission that the host 2702 initiated, in accordance with the teachings of the embodiments described throughout this disclosure. In step 2714, the UE 2706 receives the user data carried in the transmission, which may be performed by a client application executed on the UE 2706 associated with the host application executed by the host 2702.

In some examples, the UE 2706 executes a client application which provides user data to the host 2702. The user data may be provided in reaction or response to the data received from the host 2702. Accordingly, in step 2716, the UE 2706 may provide user data, which may be performed by executing the client application. In providing the user data, the client application may further consider user input received from the user via an input/output interface of the UE

2706. Regardless of the specific manner in which the user data was provided, the UE 2706 initiates, in step 2718, transmission of the user data towards the host 2702 via the network node 2704. In step 2720, in accordance with the teachings of the embodiments described throughout this disclosure, the network node 2704 receives user data from the UE 2706 and initiates transmission of the received user data towards the host 2702. In step 2722, the host 2702 receives the user data carried in the transmission initiated by the UE 2706.

One or more of the various embodiments improve the performance of OTT services provided to the UE 2706 using the OTT connection 2750, in which the wireless connection 2770 forms the last segment. More precisely, the teachings of these embodiments provide mapping of interlaces for transmission on unlicensed spectrum to sub-channels in SL resource pools, thereby facilitating use of SL interlaced transmission in unlicensed spectrum. Mapping between sub-channel and interlace facilitates reuse legacy procedures for SL resource allocation and transmission. Embodiments also facilitate mapping of additional RBs that do not belong to a sub-channel or that belong to a sub-channel with a smaller size, as well as to ensuring continuity in interlaces that cross adjacent channels. In this manner, embodiments facilitate SL operation in unlicensed spectrum, thereby enabling increased SL data rates needed for advanced OTT services. This increases the value of such OTT services to both end users and service providers.

In an example scenario, factory status information may be collected and analyzed by the host 2702. As another example, the host 2702 may process audio and video data which may have been retrieved from a UE for use in creating maps. As another example, the host 2702 may collect and analyze real-time data to assist in controlling vehicle congestion (e.g., controlling traffic lights). As another example, the host 2702 may store surveillance video uploaded by a UE. As another example, the host 2702 may store or control access to media content such as video, audio, VR or AR which it can broadcast, multicast or unicast to UEs. As other examples, the host 2702 may be used for energy pricing, remote control of non-time critical electrical load to balance power generation needs, location services, presentation services (such as compiling diagrams etc. from data collected from remote devices), or any other function of collecting, retrieving, storing, analyzing and/or transmitting data.

In some examples, a measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection 2750 between the host 2702 and UE 2706, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection may be implemented in software and hardware of the host 2702 and/or UE 2706. In some embodiments, sensors (not shown) may be deployed in or in association with other devices through which the OTT connection 2750 passes; the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software may compute or estimate the monitored quantities. The reconfiguring of the OTT connection 2750 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not directly alter the operation of the network node 2704. Such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary UE signaling that facilitates measurements of throughput, propagation times, latency and the like, by the host 2702. The measurements may be implemented in that software causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection 2750 while monitoring propagation times, errors, etc.

The foregoing merely illustrates the principles of the disclosure. Various modifications and alterations to the described embodiments will be apparent to those skilled in the art in view of the teachings herein. It will thus be appreciated that those skilled in the art will be able to devise numerous systems, arrangements, and procedures that, although not explicitly shown or described herein, embody the principles of the disclosure and can be thus within the spirit and scope of the disclosure. Various embodiments can be used together with one another, as well as interchangeably therewith, as should be understood by those having ordinary skill in the art.

The term unit, as used herein, can have conventional meaning in the field of electronics, electrical devices and/or electronic devices and can include, for example, electrical and/or electronic circuitry, devices, modules, processors, memories, logic solid state and/or discrete devices, computer programs or instructions for carrying out respective tasks, procedures, computations, outputs, and/or displaying functions, and so on, as such as those that are described herein.

Any appropriate steps, methods, features, functions, or benefits disclosed herein may be performed through one or more functional units or modules of one or more virtual apparatuses. Each virtual apparatus may comprise a number of these functional units. These functional units may be implemented via processing circuitry, which may include one or more microprocessor or microcontrollers, as well as other digital hardware, which may include Digital Signal Processor (DSPs), special-purpose digital logic, and the like. The processing circuitry may be configured to execute program code stored in memory, which may include one or several types of memory such as Read Only Memory (ROM), Random Access Memory (RAM), cache memory, flash memory devices, optical storage devices, *etc.* Program code stored in memory includes program instructions for executing one or more telecommunications and/or data communications protocols as well as instructions for carrying out one or more of the techniques described herein. In some implementations, the processing circuitry may be used to cause the respective functional unit to perform corresponding functions according one or more embodiments of the present disclosure.

As described herein, device and/or apparatus can be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of a device or apparatus, instead of being hardware implemented, be implemented as a software module such as a computer program or a computer program product comprising executable software code portions for execution or being run on a processor. Furthermore, functionality of a device or apparatus can be implemented by any combination of hardware and software. A device or apparatus can also be regarded as an assembly of multiple devices and/or apparatuses, whether functionally in cooperation with or independently of each other. Moreover, devices and apparatuses can be implemented in a distributed fashion throughout a system, so long as the functionality of the device or apparatus is preserved. Such and similar principles are considered as known to a skilled person.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

In addition, certain terms used in the present disclosure, including the specification and drawings, can be used synonymously in certain instances (*e.g.*, "data" and "information"). It should be understood, that although these terms (and/or other terms that can be synonymous to one another) can be used synonymously herein, there can be instances when such words can be intended to not be used synonymously. Further, to the extent that the prior art knowledge has not been explicitly incorporated by reference herein above, it is explicitly incorporated herein in its entirety. All publications referenced are incorporated herein by reference in their entireties.

Embodiments of the present disclosure also include, but are not limited to, the following enumerated examples.

A1. A method for a user equipment (UE) configured for wireless sidelink (SL) communication with one or more other UEs in a radio access network (RAN), the method comprising:

receiving, from a RAN node, a configuration for one or more SL resource pools corresponding to respective one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels, each sub-channel comprises a plurality of resource blocks (RBs) that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

A2. The method of embodiment A1, further comprising:

selecting a sub-channel from at least one SL resource pool that corresponds to at least one channel;

determining RBs comprising a first one of the interlaced resource allocations based on the selected at least one sub-channel and the first mapping; and

performing wireless SL communication using the RBs comprising the first interlaced resource allocation.

A3. The method of embodiment A2, wherein performing wireless SL communication includes one or more of the following:

performing radio measurements on the RBs comprising the first interlaced resource allocation;

based on the radio measurements, determining whether the sub-channel corresponding to the first interlaced resource allocation is free, busy, or reserved; and

transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation.

A4. The method of any of embodiments A1-A3, wherein:

the configuration is for a single SL resource pool corresponding to a single channel; and

the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations.

A5. The method of any of embodiments A1-A3, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and

the first mapping is between a first plurality of sub-channels, in each of the SL resource pools, and a first plurality of interlaced resource allocations.

A6. The method of embodiment A4 or A5, wherein:

in each SL resource pool, each sub-channel includes a second plurality of RBs; and

each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

A7. The method of embodiment A4 or A5, wherein:

in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs;

in each SL resource pool, the exception sub-channel includes less than the second plurality of RBs; and

each interlaced resource allocation comprises RBs that are variably spaced in frequency.

A8. The method of embodiment A7, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and

the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation.

A9. The method of embodiment A8, wherein

in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel; and

one of the following applies:

the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool; or

the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool.

A10. The method of embodiment A4 or A5, wherein:

each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels; and

the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations.

A11. The method of embodiment A10, wherein each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

A12. The method of any of embodiments A10-A11, wherein:

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel; and

for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel.

A13. The method of any of embodiments A10-A11, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel;

the second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel; and

the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool.

A14. The method of any of embodiments A10-A13, wherein transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation comprises one of the following with respect to the additional RBs comprising the first interlaced resource allocation:

transmitting, in the additional RBs, a repetition of data transmitted in the sub-channel RBs that are mapped to the first interlaced resource allocation; or

refraining from transmitting in one or more of the additional RBs.

A15. The method of any of embodiments A1-A3, wherein the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or

the RBs comprising sub-channels of a subset of the plurality of channels, and a subset of the plurality of interlaced resource allocations that span the subset of the plurality of channels.

B1. A method for a radio access network (RAN) node configured to facilitate wireless sidelink (SL) communication between a plurality of user equipment (UEs), the method comprising:

sending, to the plurality of UEs, a configuration for one or more SL resource pools corresponding to respective one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels,

each sub-channel comprises a plurality of resource blocks (RBs) that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

B2. The method of embodiment B1, wherein:

the configuration is for a single SL resource pool corresponding to a single channel; and

the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations.

B3. The method of embodiment B1, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

the first mapping is between a first plurality of sub-channels, in each of the SL resource pools, and a first plurality of interlaced resource allocations; and

each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

B4. The method of embodiment B2 or B3, wherein:

in each SL resource pool, each sub-channel includes a second plurality of RBs; and

each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

B5. The method of embodiment B2 or B3, wherein:

in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs;

in each SL resource pool, the exception sub-channel includes less than the second plurality of RBs; and

each interlaced resource allocation comprises RBs that are variably spaced in frequency.

B6. The method of embodiment B5, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation.

B7. The method of embodiment B6, wherein

in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel; and

one of the following applies:

the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool; or

the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool.

B8. The method of embodiment B2 or B3, wherein:

each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels; and

the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations.

B9. The method of embodiment B8, wherein each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

B10. The method of any of embodiments B8-B9, wherein:

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel; and

for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel.

B11. The method of any of embodiments B8-B9, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel;

the second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel; and the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool.

B12. The method of embodiment B1, wherein the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or

the RBs comprising sub-channels of a subset of the plurality of channels, and a subset of the plurality of interlaced resource allocations that span the subset of the plurality of channels.

B13. The method of embodiment B1, wherein:

the configuration sent to a first UE is for a plurality of SL resource pools corresponding to a respective plurality of channels, and

the configuration sent to a second UE includes is for a subset of the plurality of SL resource pools corresponding to a respective subset of the plurality of channels.

C1. A user equipment (UE) configured for wireless sidelink (SL) communication with one or more other UEs in a radio access network (RAN), the UE comprising:

communication interface circuitry configured to communicate with the one or more other UEs and with a RAN node; and

processing circuitry operatively coupled to the communication interface circuitry, whereby the processing circuitry and the communication interface circuitry are configured to perform operations corresponding to any of the methods of embodiments A1-A15.

C2. A user equipment (UE) configured for wireless sidelink (SL) communication with one or more other UEs in a radio access network (RAN), the UE being further configured to perform operations corresponding to any of the methods of embodiments A1-A15.

C3. A non-transitory, computer-readable medium storing computer-executable instructions that, when executed by processing circuitry of a user equipment (UE) configured for wireless sidelink (SL) communication with one or more other UEs in a radio access network (RAN), configure the UE to perform operations corresponding to any of the methods of embodiments A1-A15.

C4. A computer program product comprising computer-executable instructions that, when executed by processing circuitry of a user equipment (UE) configured for wireless sidelink (SL) communication with one or more other UEs in a radio access network (RAN), configure the UE to perform operations corresponding to any of the methods of embodiments A1-A15.

D1. A radio access network (RAN) node configured to facilitate wireless sidelink (SL) communication between a plurality of user equipment (UEs), the RAN node comprising:

communication interface circuitry configured to communicate with the plurality of UEs; and

processing circuitry operatively coupled to the communication interface circuitry, whereby the processing circuitry and the communication interface circuitry are configured to perform operations corresponding to any of the methods of embodiments B1-B13.

D2. A radio access network (RAN) node configured to facilitate wireless sidelink (SL) communication between a plurality of user equipment (UEs), the RAN node being further configured to perform operations corresponding to any of the methods of embodiments B1-B13.

D3. A non-transitory, computer-readable medium storing computer-executable instructions that, when executed by processing circuitry of a radio access network (RAN) node configured to facilitate wireless sidelink (SL) communication between a plurality of user equipment (UEs), configure the RAN node to perform operations corresponding to any of the methods of embodiments B1-B13.

D4. A computer program product comprising computer-executable instructions that, when executed by processing circuitry of a radio access network (RAN) node configured to facilitate wireless sidelink (SL) communication between a plurality of user equipment (UEs), configure the RAN node to perform operations corresponding to any of the methods of embodiments B1-B13.

CLAIMS

1. A method for a user equipment, UE, (810, 820; 2212, 2212a, 2212b; 2300) for wireless sidelink, SL, communication with one or more other UEs (810, 820; 2212, 2212a, 2212b; 2300), the method comprising:

determining (2010) a configuration for one or more SL resource pools corresponding to one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels,

each sub-channel comprises a plurality of resource blocks, RBs, that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

2. The method of claim 1, further comprising:

selecting (2020) a sub-channel from at least one SL resource pool that corresponds to at least one channel;

determining (2030) RBs comprising a first one of the interlaced resource allocations based on the selected at least one sub-channel and the first mapping; and

performing (2040) wireless SL communication using the RBs comprising the first interlaced resource allocation.

3. The method of claim 2, wherein performing wireless SL communication includes one or more of the following:

performing (2041) radio measurements on the RBs comprising the first interlaced resource allocation;

based on the radio measurements, determining (2042) whether the sub-channel corresponding to the first interlaced resource allocation is free, busy, or reserved; and

transmitting (2043) data to one or more other UEs (810, 820; 2212, 2212a, 2212b; 2300) using the RBs comprising the first interlaced resource allocation.

4. The method of any of claims 1-3, wherein:

the configuration is for a single SL resource pool corresponding to a single channel; and the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations.

5. The method of any of claims 1-3, wherein:
the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and
the first mapping is between a first plurality of sub-channels, in each of the SL resource pools, and a first plurality of interlaced resource allocations.

6. The method of claim 4 or 5, wherein:
in each SL resource pool, each sub-channel includes a second plurality of RBs; and
each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

7. The method of claim 4 or 5, wherein:
in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs;
in each SL resource pool, the exception sub-channel includes less than the second plurality of RBs; and
each interlaced resource allocation comprises RBs that are variably spaced in frequency.

8. The method of claim 7, wherein:
the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and
the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation.

9. The method of claim 8, wherein
in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel; and
one of the following applies:
the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool; or
the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool.

10. The method of claim 4 or 5, wherein:

each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels; and

the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations.

11. The method of claim 10, wherein each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

12. The method of claim 10 or 11, wherein:

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel; and

for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel.

13. The method of claim 10 or 11, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel;

the second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel; and

the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool.

14. The method of any of claims 10-13, wherein transmitting data to one or more other UEs (810, 820; 2212, 2212a, 2212b; 2300) using the RBs comprising the first interlaced resource allocation comprises one of the following with respect to the additional RBs comprising the first interlaced resource allocation:

transmitting, in the additional RBs, a repetition of data transmitted in the sub-channel RBs that are mapped to the first interlaced resource allocation; or

refraining from transmitting in one or more of the additional RBs.

15. The method of any of claims 1-3, wherein the configuration is for a plurality of SL resource pools corresponding to a respective plurality of channels, and the first mapping is between one of the following:

the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or

the RBs comprising sub-channels of a subset of the plurality of channels, and a subset of the plurality of interlaced resource allocations that span the subset of the plurality of channels.

16. The method of any of claims 1-15, wherein determining the configuration comprises receiving the configuration from a radio access network, RAN, node (830; 2210, 2210A, 2210B; 2400).

17. The method of any of claims 1-16, wherein the configuration is at least in part based on pre-configuration of the UE (810, 820; 2212, 2212a, 2212b; 2300).

18. A method for a radio access network, RAN, node (830; 2210, 2210A, 2210B; 2400) to facilitate wireless sidelink, SL, communication between a plurality of user equipment, UEs, (810, 820; 2212, 2212a, 2212b; 2300) the method comprising:

sending (2110), to the plurality of UEs (810, 820; 2212, 2212a, 2212b; 2300), a configuration for one or more SL resource pools corresponding to one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels,

each sub-channel comprises a plurality of resource blocks, RBs, that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

19. The method of claim 18, wherein:

the configuration is for a single SL resource pool corresponding to a single channel; and

the first mapping is between a first plurality of sub-channels and a first plurality of interlaced resource allocations.

20. The method of claim 18, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

the first mapping is between a first plurality of sub-channels, in each of the SL resource pools, and a first plurality of interlaced resource allocations; and

each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

21. The method of claim 19 or 20, wherein:

in each SL resource pool, each sub-channel includes a second plurality of RBs; and

each interlaced resource allocation comprises RBs that occur every first plurality of RBs.

22. The method of claim 19 or 20, wherein:

in each SL resource pool, all except one of the first plurality of sub-channels include a second plurality of RBs;

in each SL resource pool, the exception sub-channel includes less than the second plurality of RBs; and

each interlaced resource allocation comprises RBs that are variably spaced in frequency.

23. The method of claim 22, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels; and

the exception sub-channels for the plurality of SL resource pools are mapped to a single interlaced resource allocation.

24. The method of claim 23, wherein

in each SL resource pool, the exception sub-channel is adjacent in frequency to a last RB of a last sub-channel; and

one of the following applies:

the exception sub-channel from each SL resource pool is only mapped in sequence with RBs of other sub-channels of the same SL resource pool; or

the exception sub-channel from at least one SL resource is mapped out of sequence with RBs of other sub-channels of the same SL resource pool.

25. The method of claim 19 or 20, wherein:

each SL resource pool also includes additional RBs that are not part of the plurality of sub-channels; and

the configuration also includes a second mapping between the additional RBs and the first plurality of interlaced resource allocations.

26. The method of claim 25, wherein each sub-channel includes a first number of RBs, and the number of RBs comprising the additional RBs is less than the first number.

27. The method of claim 25 or 26, wherein:

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel; and

for each SL resource pool, the second mapping is a continuation of the first mapping as applied to the last RB of the last sub-channel.

28. The method of claim 25 or 26, wherein:

the configuration is for a plurality of SL resource pools corresponding to a plurality of channels;

in each SL resource pool, the additional RBs are contiguous and adjacent in frequency to a last RB of a last sub-channel;

the second mapping for a lowest-frequency one of the SL resource pools is a continuation of the first mapping as applied to the last RB of the last sub-channel; and

the second mapping for other SL resource pools is a continuation of the second mapping as applied to additional RBs of a next-lowest-frequency SL resource pool.

29. The method of any of claims 18-28, wherein the configuration is for a plurality of SL resource pools corresponding to a plurality of channels, and the first mapping is between one of the following:

the RBs comprising sub-channels of the plurality of channels, and a plurality of interlaced resource allocations that span the plurality of channels; or

the RBs comprising sub-channels of a subset of the plurality of channels, and a subset of the plurality of interlaced resource allocations that span the subset of the plurality of channels.

30. The method of any of claims 18-29, wherein:

the configuration sent to a first UE (810, 820; 2212, 2212a, 2212b; 2300) is for a plurality of SL resource pools corresponding to a respective plurality of channels, and

the configuration sent to a second UE (810, 820; 2212, 2212a, 2212b; 2300) includes is for a subset of the plurality of SL resource pools corresponding to a respective subset of the plurality of channels.

31. A user equipment, UE, (810, 820; 2212, 2212a, 2212b; 2300) for wireless sidelink, SL, communication with one or more other UEs (810, 820; 2212, 2212a, 2212b; 2300), the UE (810, 820; 2212, 2212a, 2212b; 2300) being configured to:

determine a configuration for one or more SL resource pools corresponding to one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels,

each sub-channel comprises a plurality of resource blocks, RBs, that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

32. The UE (810, 820; 2212, 2212a, 2212b; 2300) of claim 31, further configured to perform operations corresponding to any of the methods of claims 2-17.

33. The UE (810, 820; 2212, 2212a, 2212b; 2300) of claim 31 or 32, comprising:

processing circuitry (2302) and a memory (2310) storing computer-executable instructions that, when executed by the processing circuitry (2302), configure the UE (810, 820; 2212, 2212a, 2212b; 2300) to perform operations corresponding to any of the methods of claims 1-17.

34. A computer program or computer program product comprising computer-executable instructions that, when executed by processing circuitry (2302) of a user equipment, UE, (810, 820; 2212, 2212a, 2212b; 2300), configure the UE (810, 820; 2212, 2212a, 2212b; 2300) to perform operations corresponding to any of the methods of claims 1-17.

35. A radio access network, RAN, node (830; 2210, 2210A, 2210B; 2400) for facilitating wireless sidelink, SL, communication between a plurality of user equipments, UEs, (810, 820; 2212, 2212a, 2212b; 2300), the RAN node (830; 2210, 2210A, 2210B; 2400) being configured

to:

send, to the plurality of UEs (810, 820; 2212, 2212a, 2212b; 2300), a configuration for one or more SL resource pools corresponding to one or more channels, wherein:

each SL resource pool comprises a plurality of non-overlapping sub-channels,

each sub-channel comprises a plurality of resource blocks, (RBs, that are contiguous and non-overlapping in frequency, and

the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.

36. The RAN node (830; 2210, 2210A, 2210B; 2400) of claim 35, further configured to perform operations corresponding to any of the methods of claims 19-30.

37. The RAN node (830; 2210, 2210A, 2210B; 2400) of claim 35 or 36, comprising:

processing circuitry (2402) and a memory (2404) storing computer-executable instructions that, when executed by the processing circuitry (2402), configure the RAN node (830; 2210, 2210A, 2210B; 2400) to perform operations corresponding to any of the methods of claims 18-30.

38. A computer program or computer program product comprising computer-executable instructions that, when executed by processing circuitry (2402) of a radio access network, RAN, node (830; 2210, 2210A, 2210B; 2400), configure the RAN node (830; 2210, 2210A, 2210B; 2400) to perform operations corresponding to any of the methods of claims 18-30.

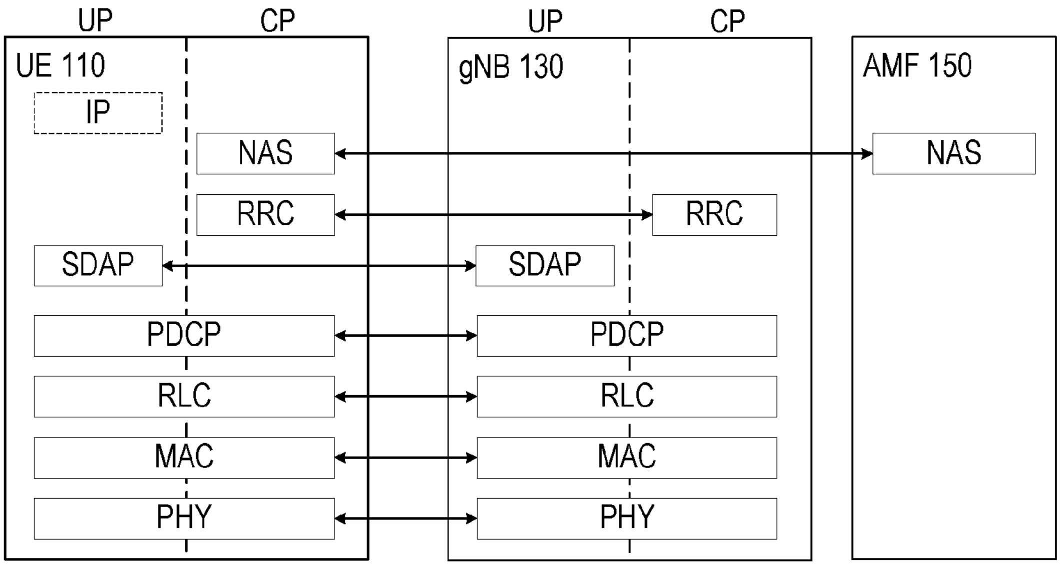

UP
CP
UE 110
IP
NAS
RRC
SDAP
PDCP
RLC
MAC
PHY
UP
CP
gNB 130
RRC
SDAP
PDCP
RLC
MAC
PHY
AMF 150
NAS

FIG. 1

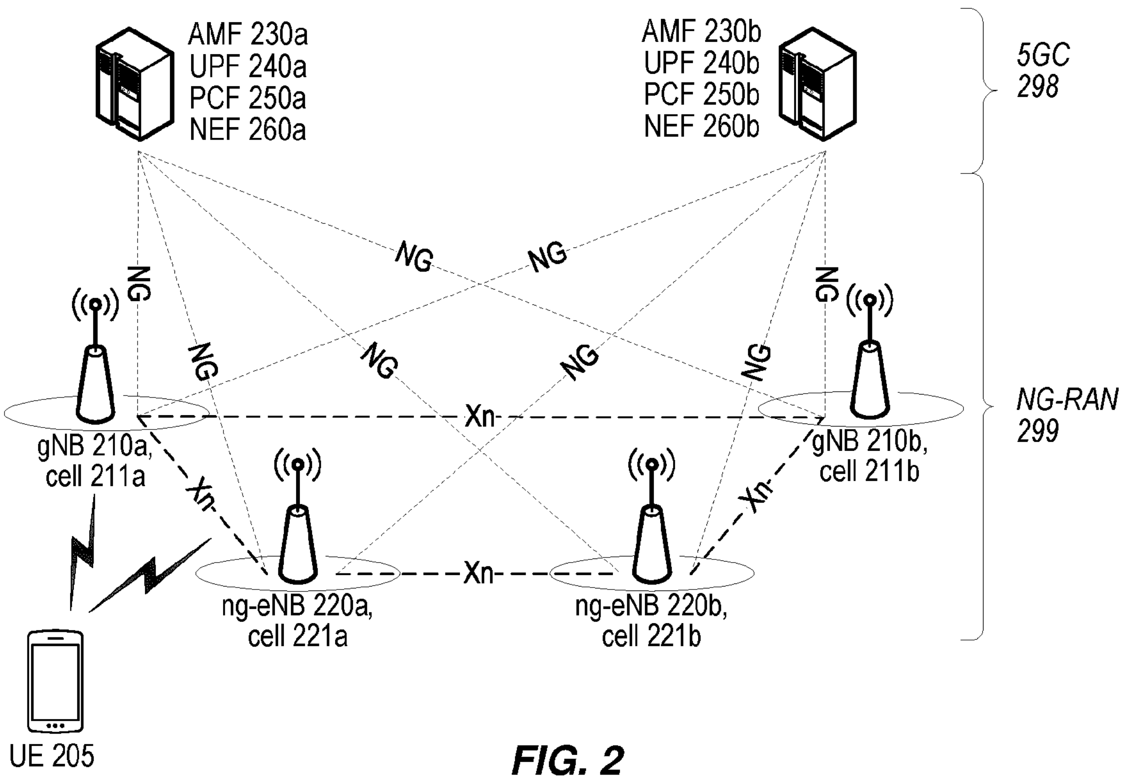

AMF 230a
UPF 240a
PCF 250a
NEF 260a
AMF 230b
UPF 240b
PCF 250b
NEF 260b
5GC
298
NG
Xn
gNB 210a,
cell 211a
gNB 210b,
cell 211b
ng-eNB 220a,
cell 221a
ng-eNB 220b,
cell 221b
NG-RAN
299
UE 205

FIG. 2

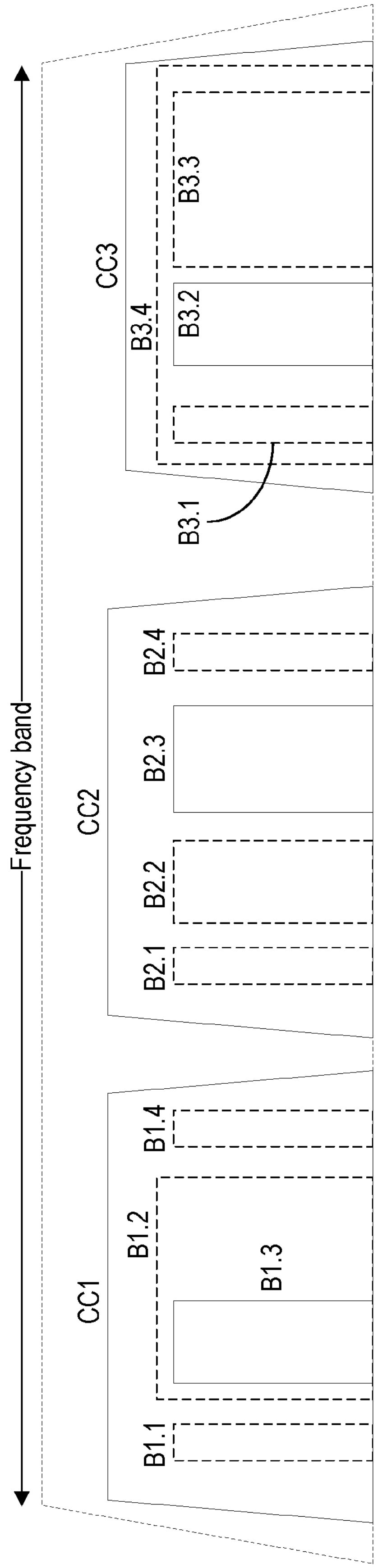


FIG. 4

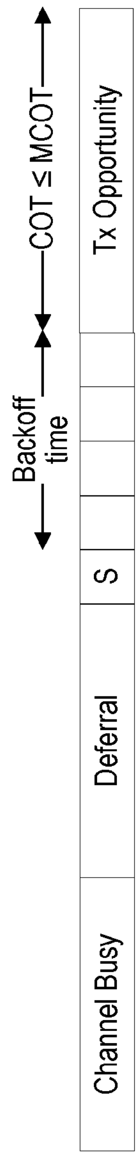


FIG. 3

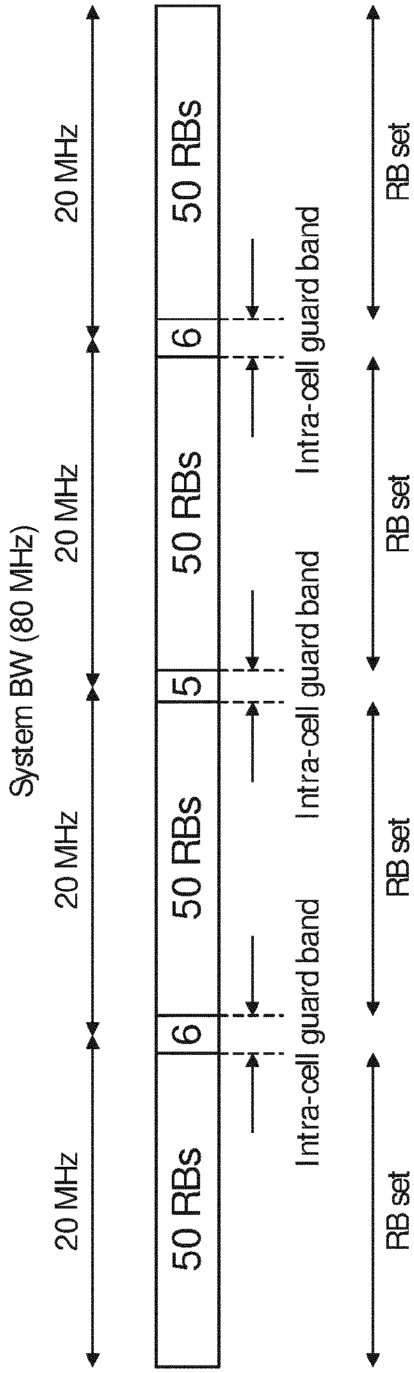


FIG. 5

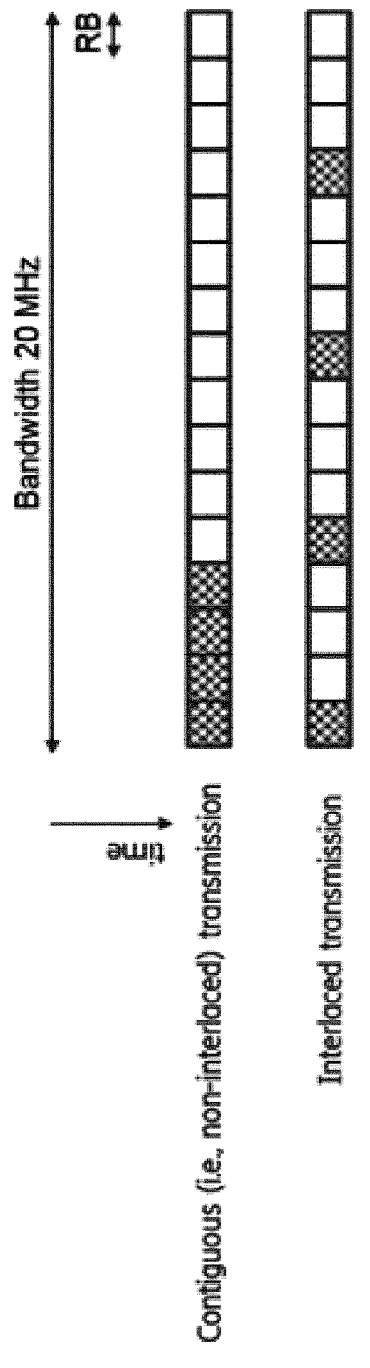


FIG. 6

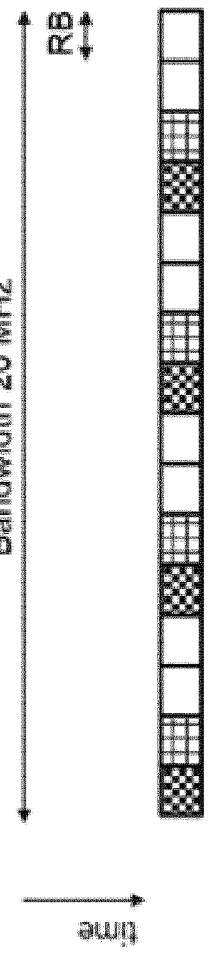


FIG. 7

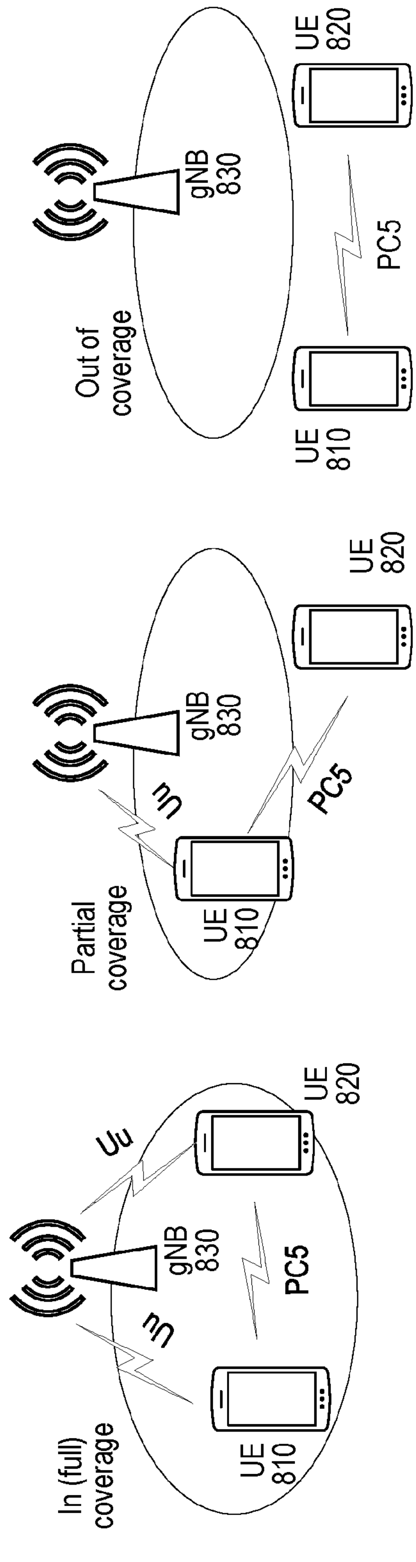


FIG. 8

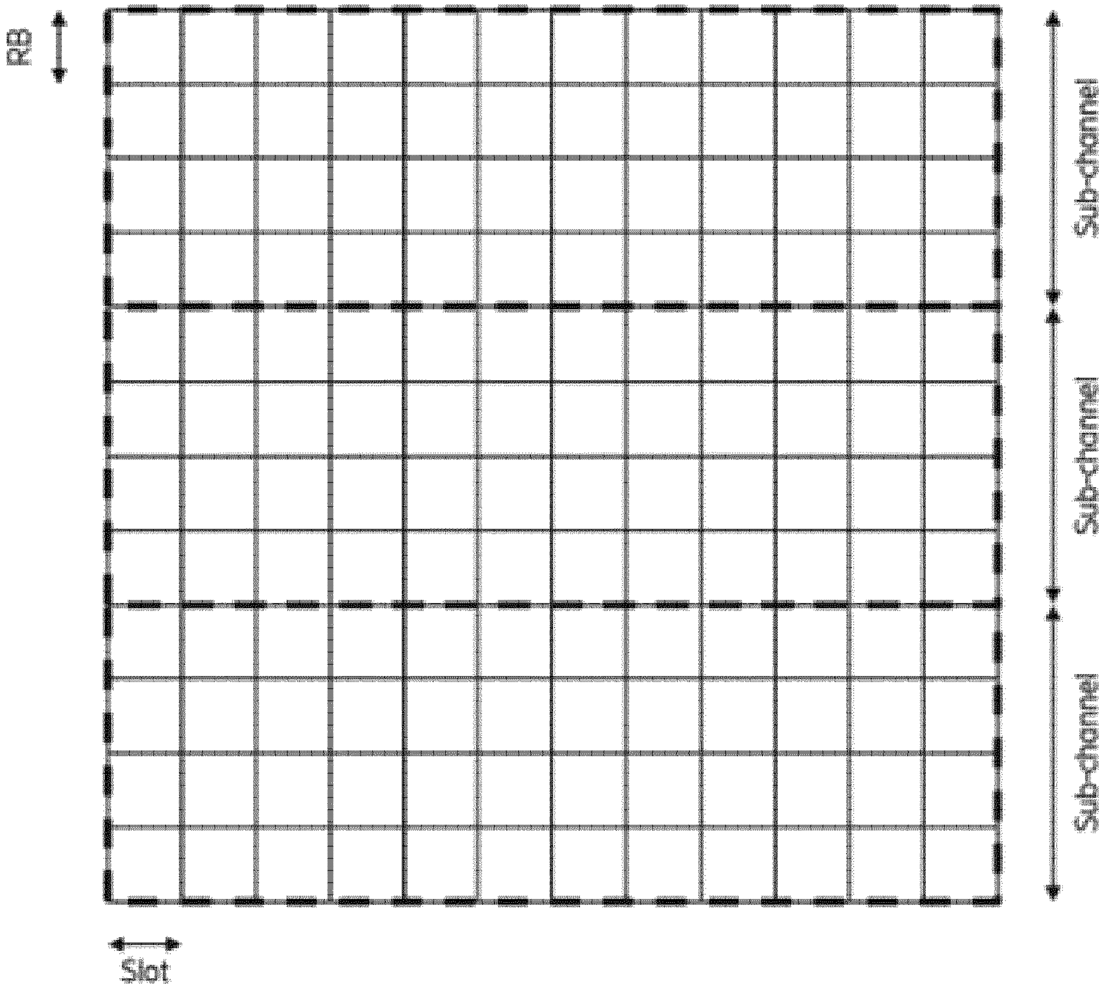


FIG. 9

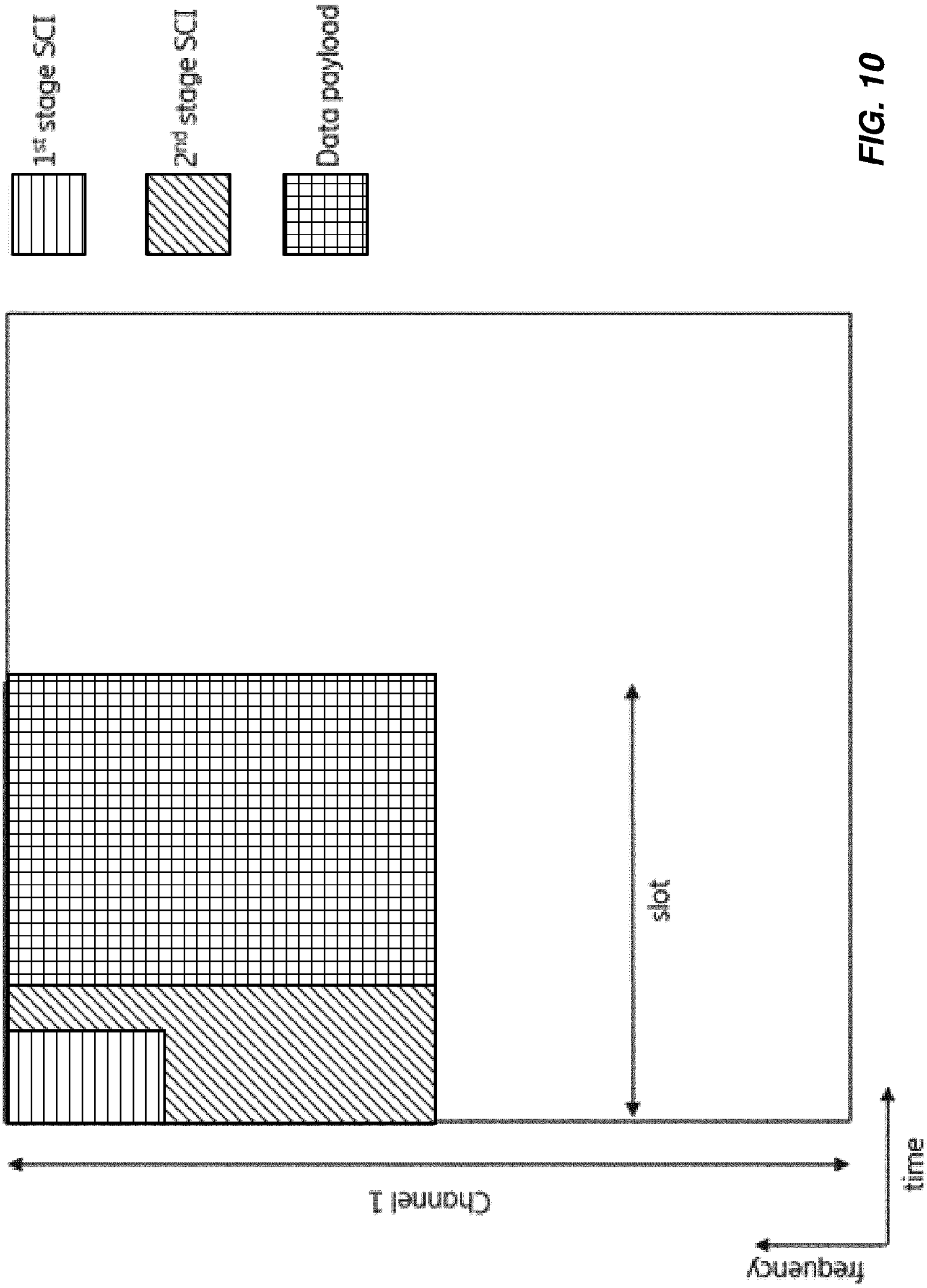

1st stage SCI
2nd stage SCI
Data payload
slot
Channel 1
time
frequency

FIG. 10

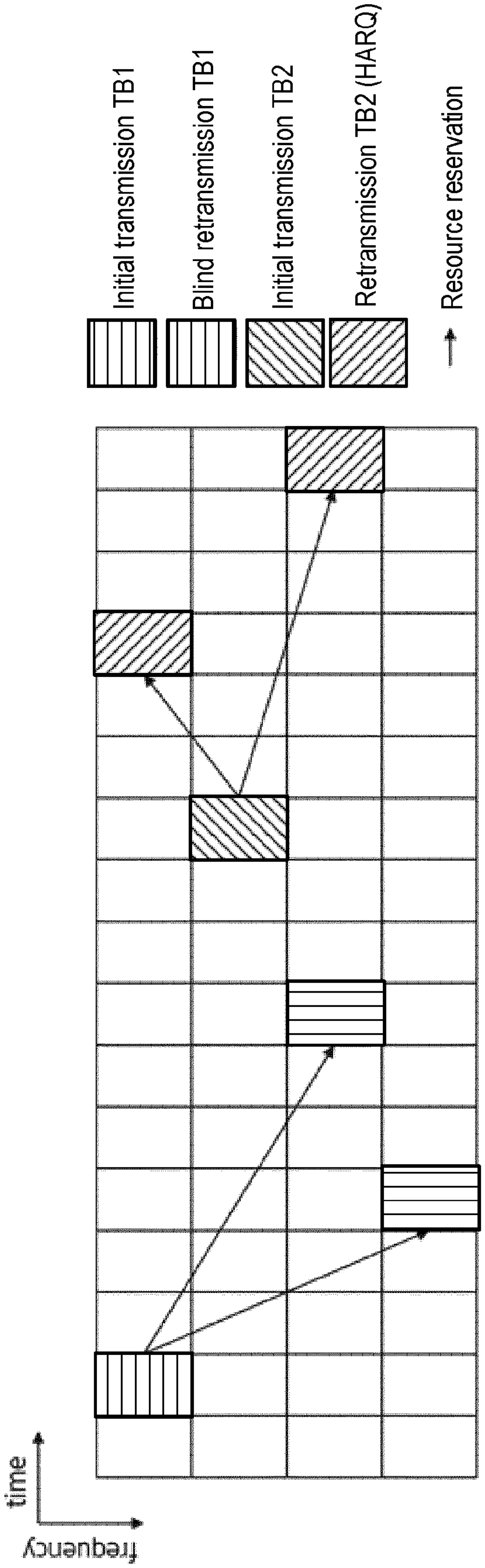

Initial transmission TB1
Blind retransmission TB1
Initial transmission TB2
Retransmission TB2 (HARQ)
Resource reservation
time
frequency

FIG. 11

FIG. 12

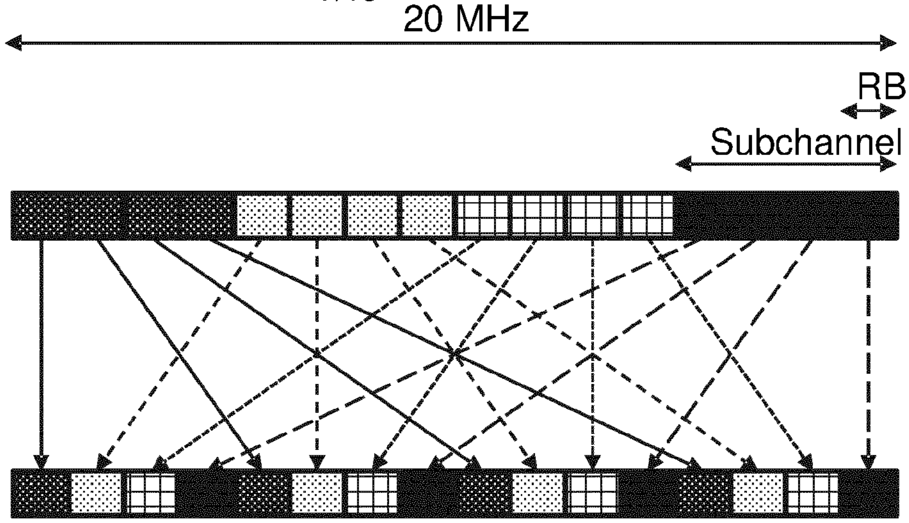


FIG. 13

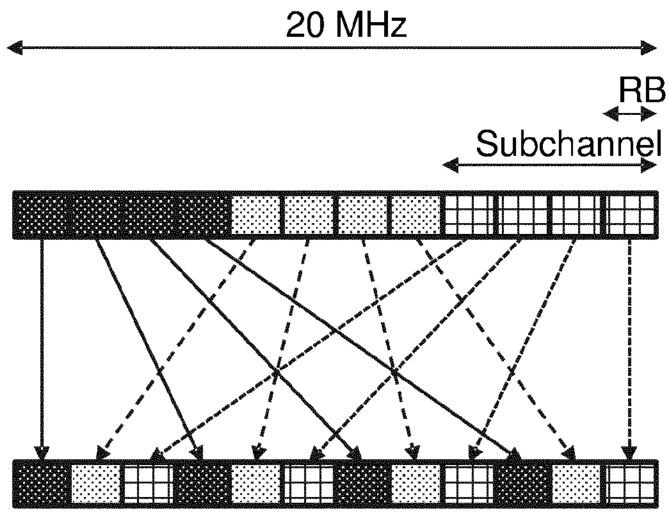
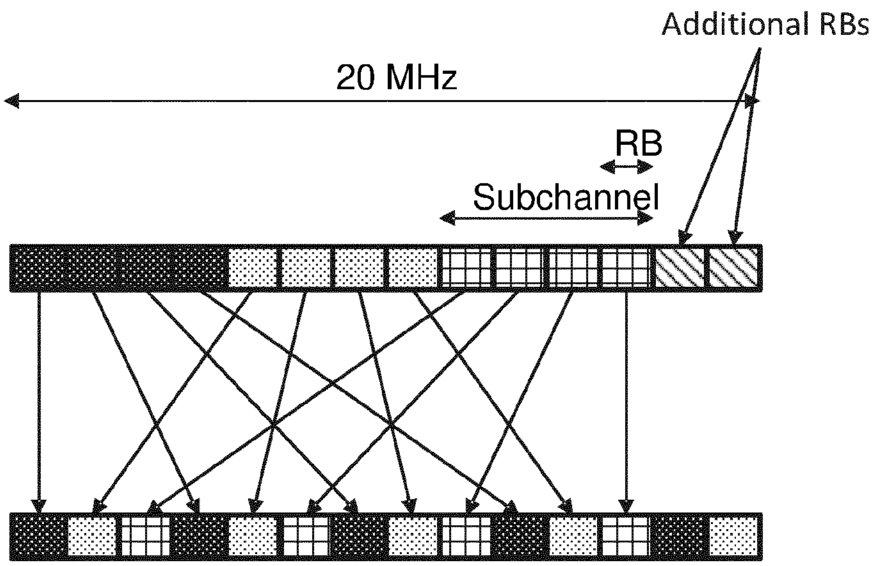


FIG. 14



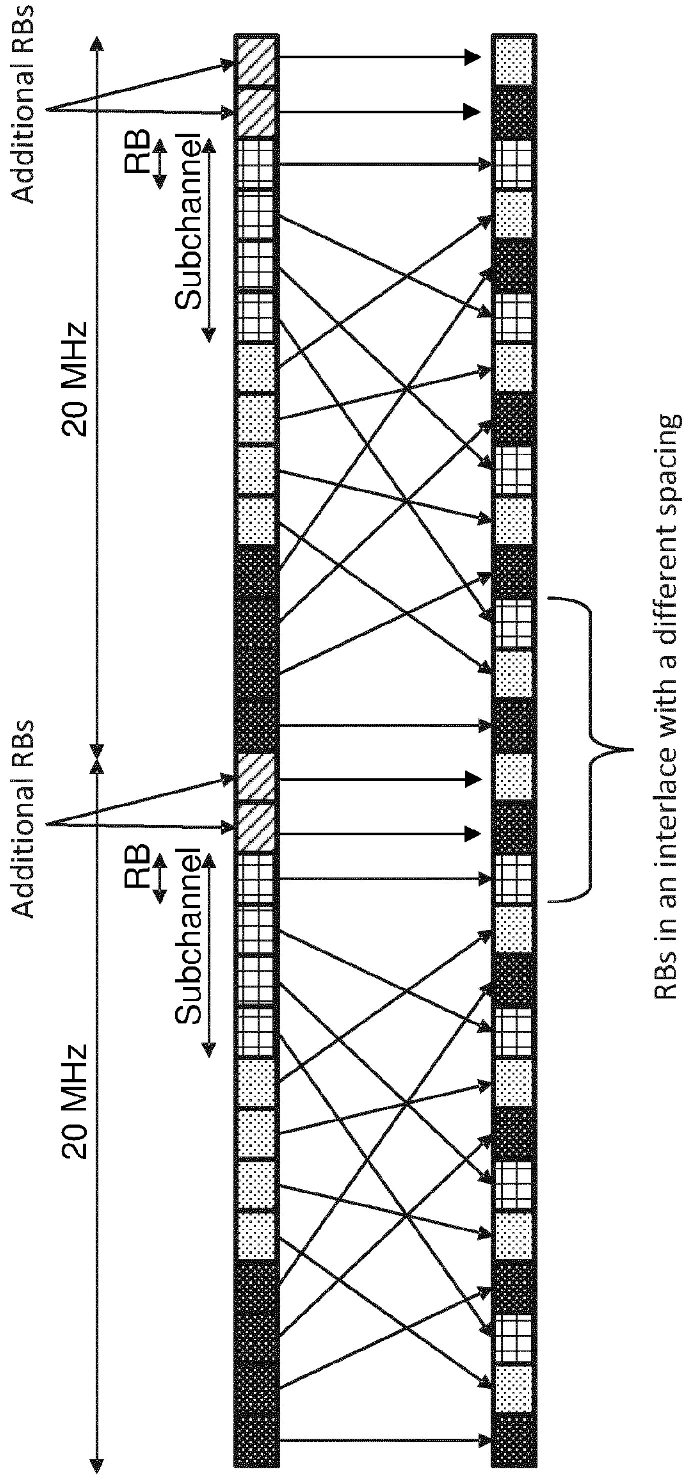

Additional RBs
RB
Subchannel
20 MHz
Additional RBs
RB
Subchannel
20 MHz
RBs in an interlace with a different spacing

FIG. 15

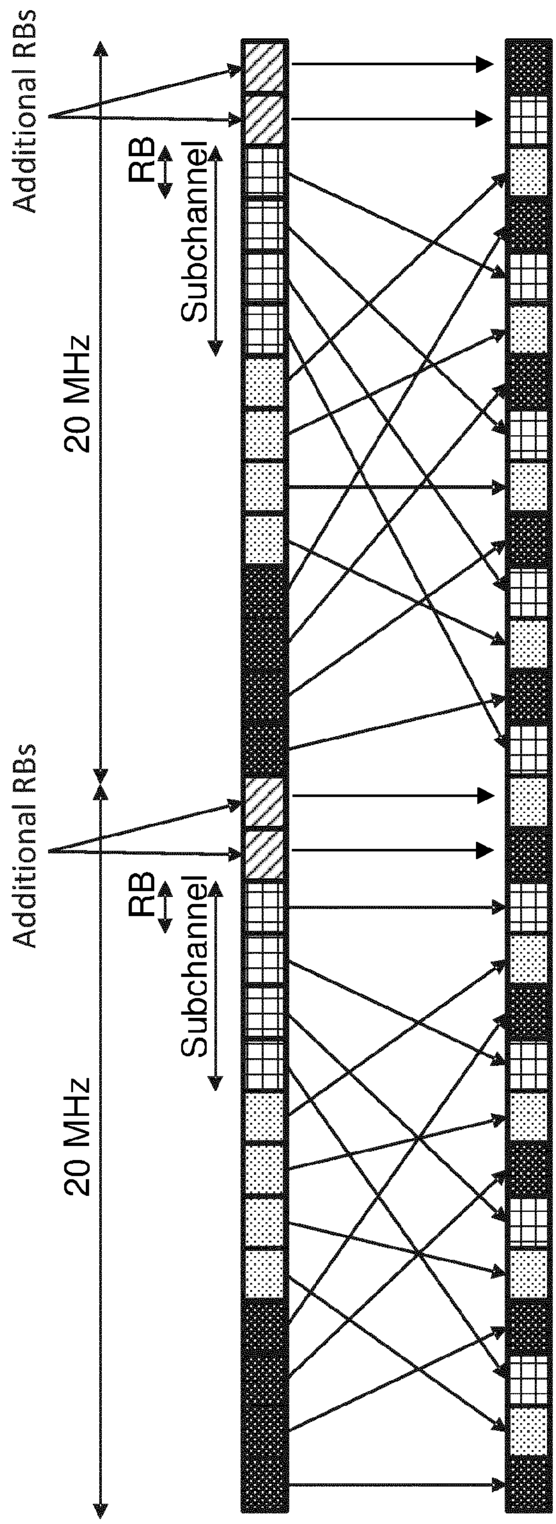

Additional RBs
RB
Subchannel
20 MHz
Additional RBs
RB
Subchannel
20 MHz

FIG. 16

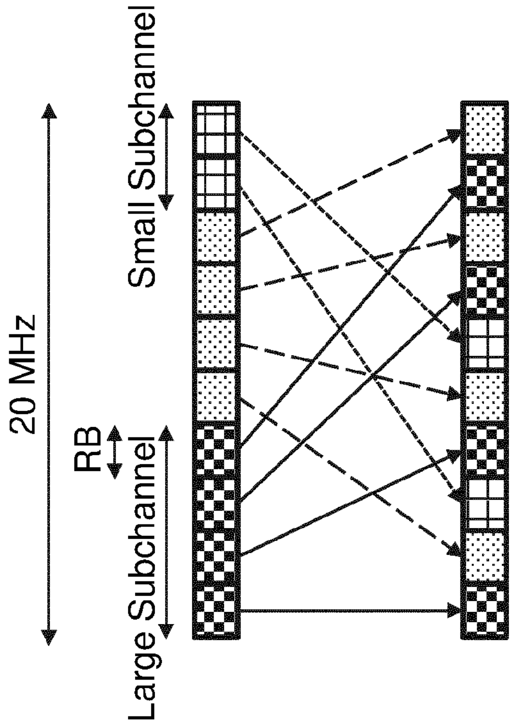

Small Subchannel
20 MHz
RB
Large Subchannel

FIG. 17

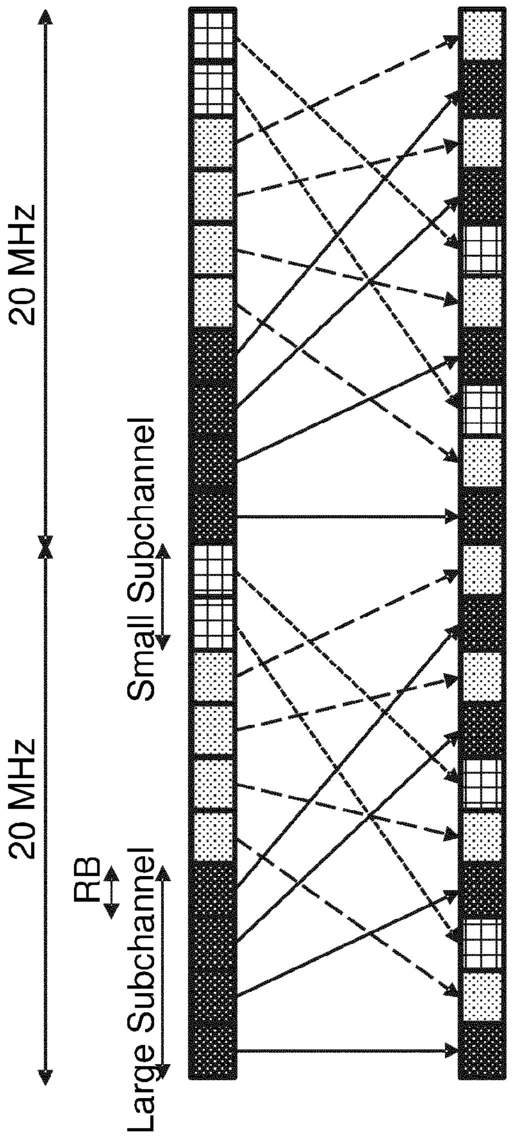

20 MHz
20 MHz
Small Subchannel
RB
Large Subchannel

FIG. 18

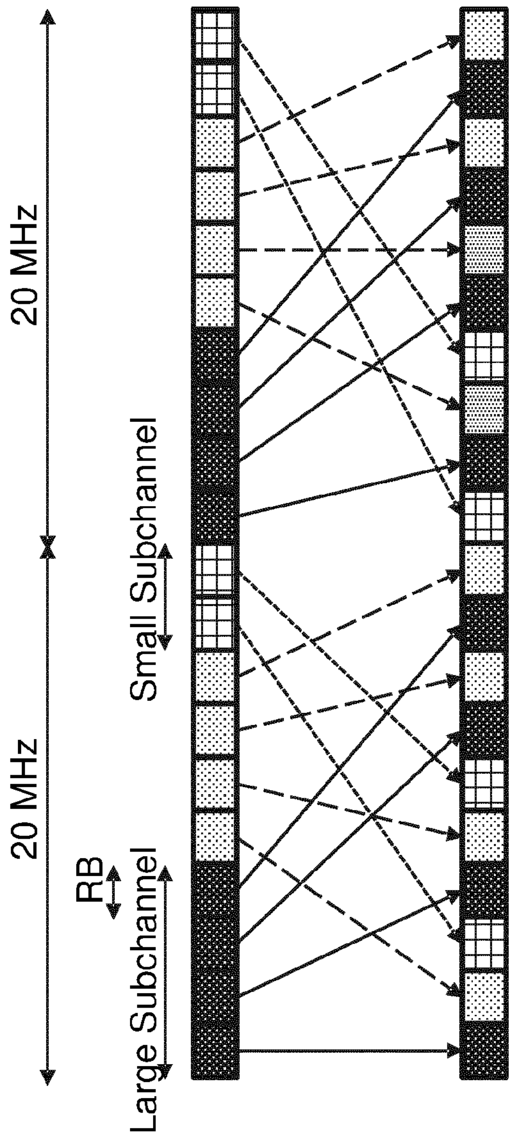

20 MHz
20 MHz
Small Subchannel
RB
Large Subchannel

FIG. 19

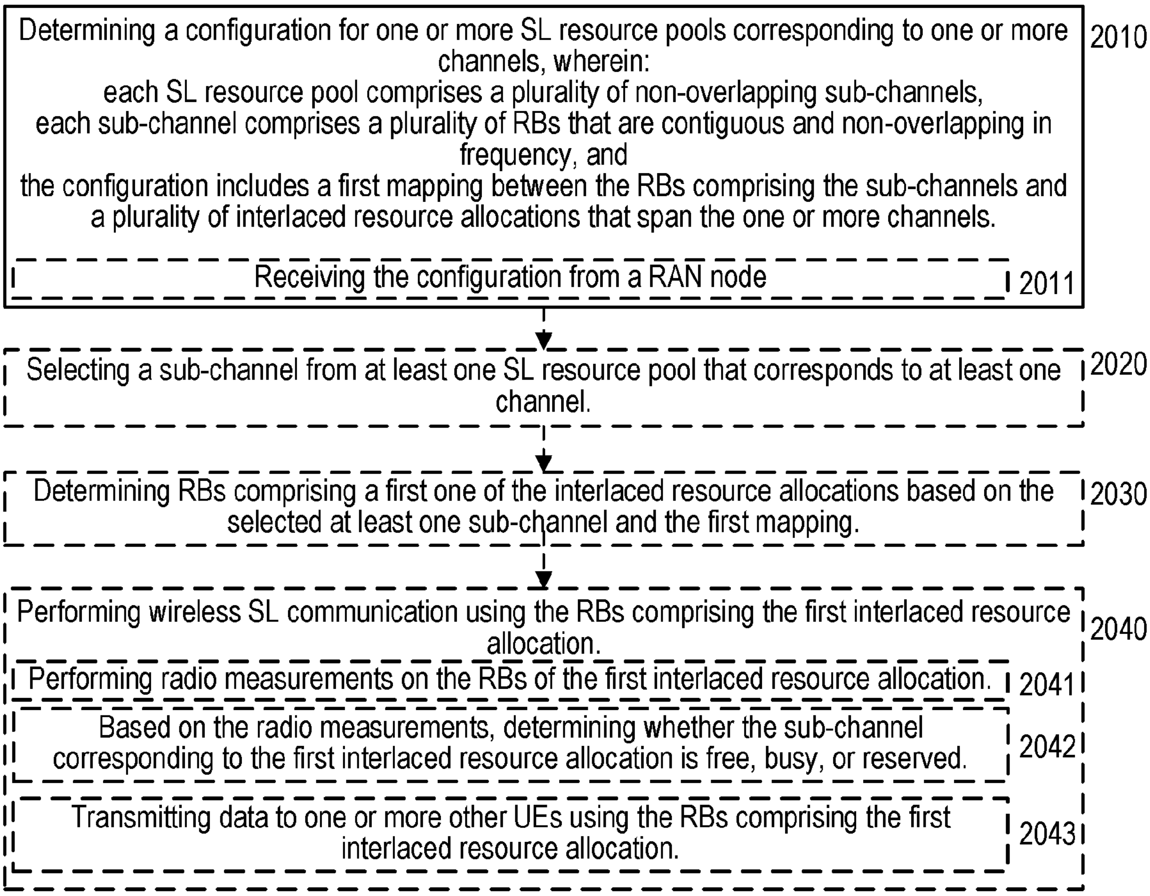

Determining a configuration for one or more SL resource pools corresponding to one or more channels, wherein:
each SL resource pool comprises a plurality of non-overlapping sub-channels,
each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency, and
the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.
2010
Receiving the configuration from a RAN node
2011
Selecting a sub-channel from at least one SL resource pool that corresponds to at least one channel.
2020
Determining RBs comprising a first one of the interlaced resource allocations based on the selected at least one sub-channel and the first mapping.
2030
Performing wireless SL communication using the RBs comprising the first interlaced resource allocation.
2040
Performing radio measurements on the RBs of the first interlaced resource allocation.
2041
Based on the radio measurements, determining whether the sub-channel corresponding to the first interlaced resource allocation is free, busy, or reserved.
2042
Transmitting data to one or more other UEs using the RBs comprising the first interlaced resource allocation.
2043

FIG. 20

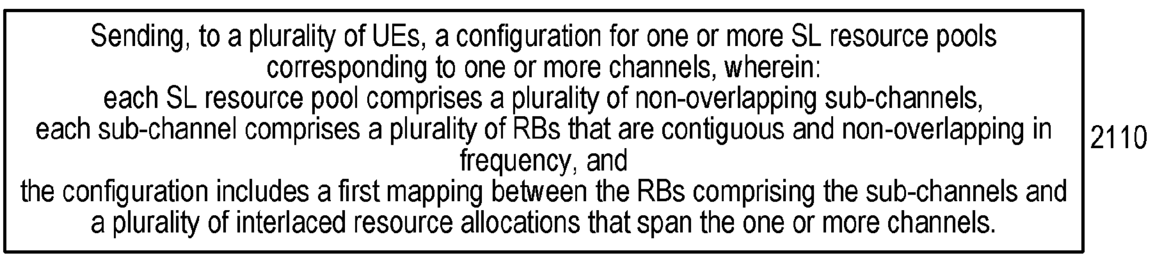

Sending, to a plurality of UEs, a configuration for one or more SL resource pools corresponding to one or more channels, wherein:
each SL resource pool comprises a plurality of non-overlapping sub-channels,
each sub-channel comprises a plurality of RBs that are contiguous and non-overlapping in frequency, and
the configuration includes a first mapping between the RBs comprising the sub-channels and a plurality of interlaced resource allocations that span the one or more channels.
2110

FIG. 21

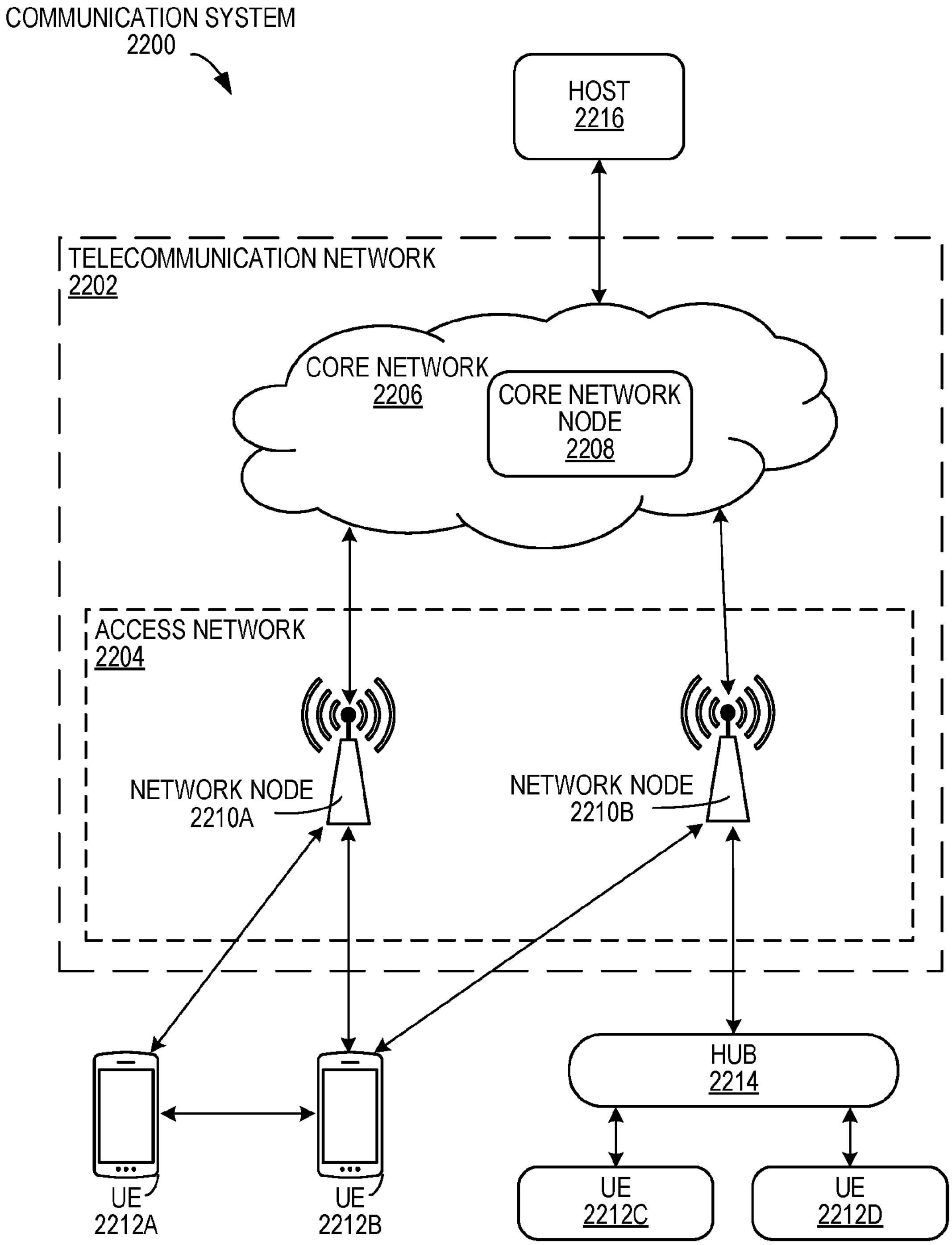

COMMUNICATION SYSTEM
2200
HOST
2216
TELECOMMUNICATION NETWORK
2202
CORE NETWORK
2206
CORE NETWORK
NODE
2208
ACCESS NETWORK
2204
NETWORK NODE
2210A
NETWORK NODE
2210B
HUB
2214
UE
2212A
UE
2212B
UE
2212C
UE
2212D

FIG. 22

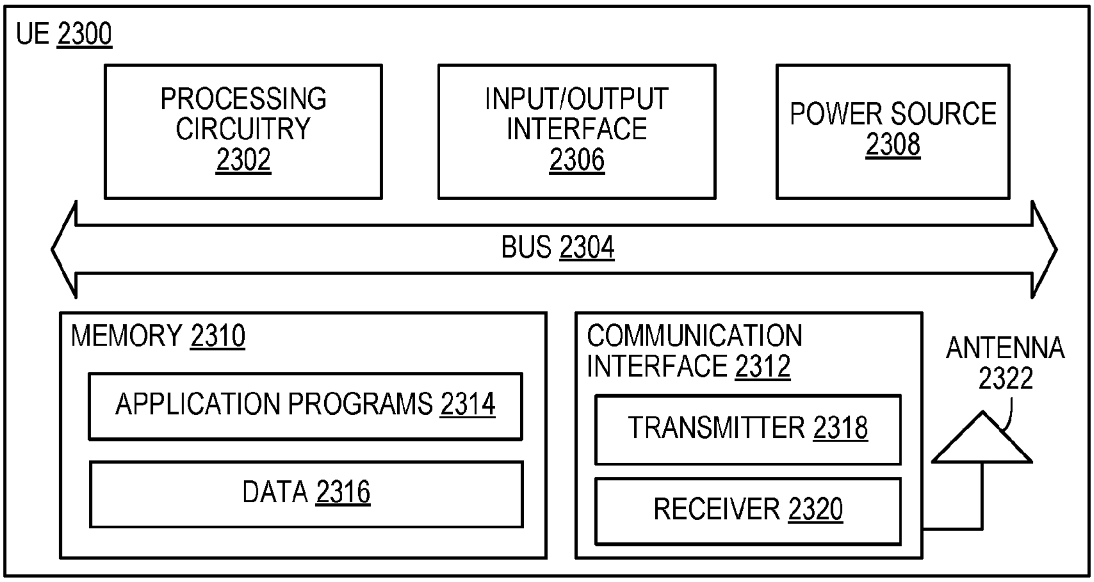

UE 2300
PROCESSING CIRCUITRY 2302
INPUT/OUTPUT INTERFACE 2306
POWER SOURCE 2308
BUS 2304
MEMORY 2310
APPLICATION PROGRAMS 2314
DATA 2316
COMMUNICATION INTERFACE 2312
TRANSMITTER 2318
RECEIVER 2320
ANTENNA 2322

FIG. 23

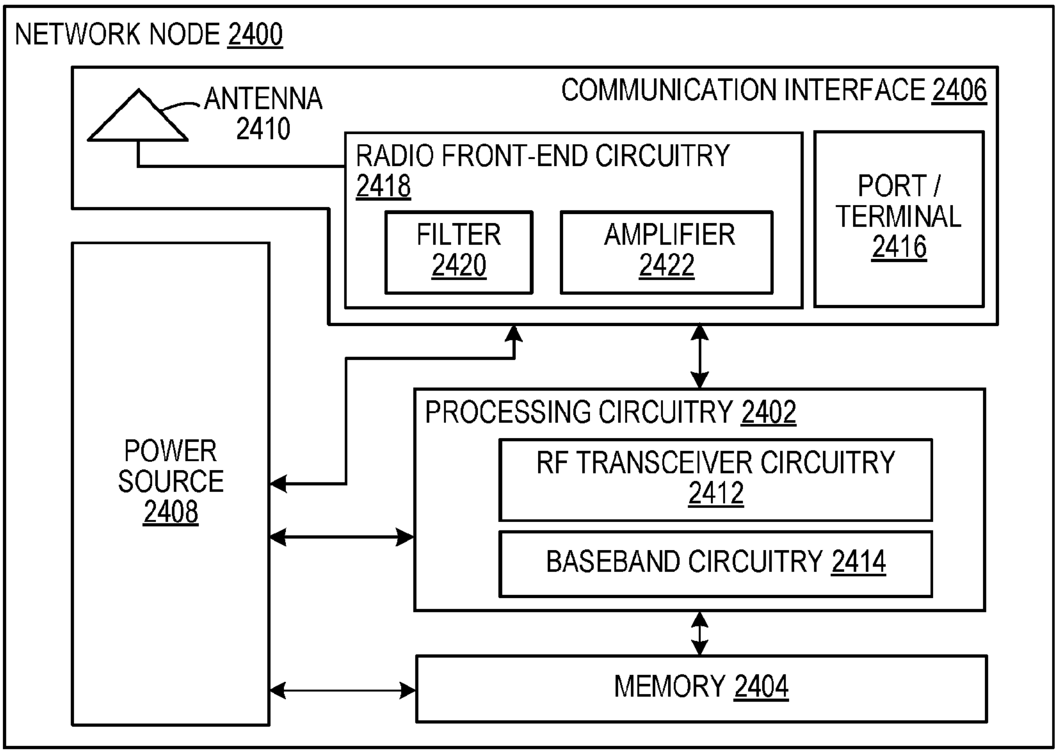

NETWORK NODE 2400
ANTENNA 2410
COMMUNICATION INTERFACE 2406
RADIO FRONT-END CIRCUITRY 2418
FILTER 2420
AMPLIFIER 2422
PORT / TERMINAL 2416
POWER SOURCE 2408
PROCESSING CIRCUITRY 2402
RF TRANSCEIVER CIRCUITRY 2412
BASEBAND CIRCUITRY 2414
MEMORY 2404

FIG. 24

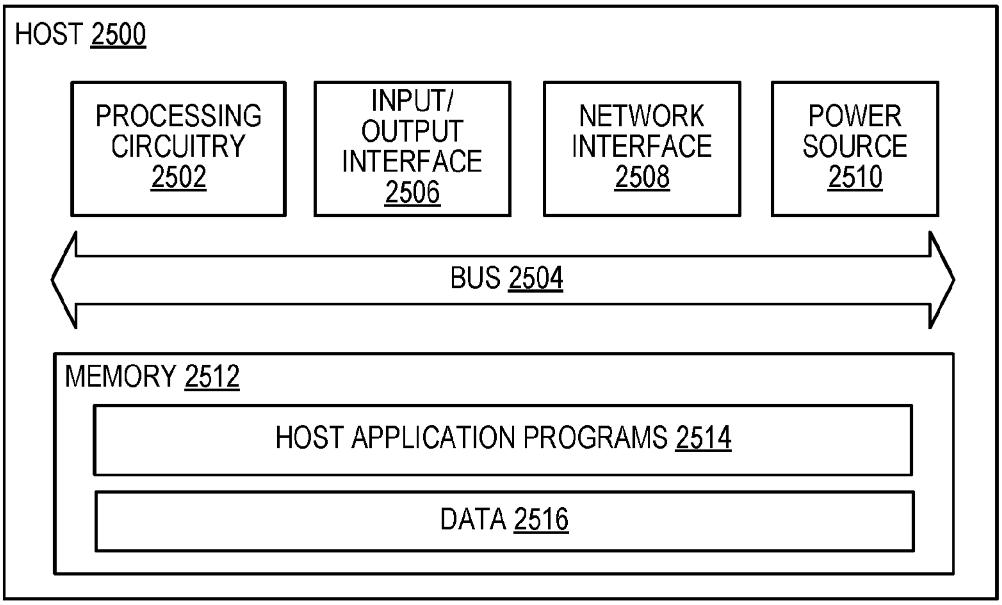

HOST 2500
PROCESSING CIRCUITRY 2502
INPUT/ OUTPUT INTERFACE 2506
NETWORK INTERFACE 2508
POWER SOURCE 2510
BUS 2504
MEMORY 2512
HOST APPLICATION PROGRAMS 2514
DATA 2516

FIG. 25

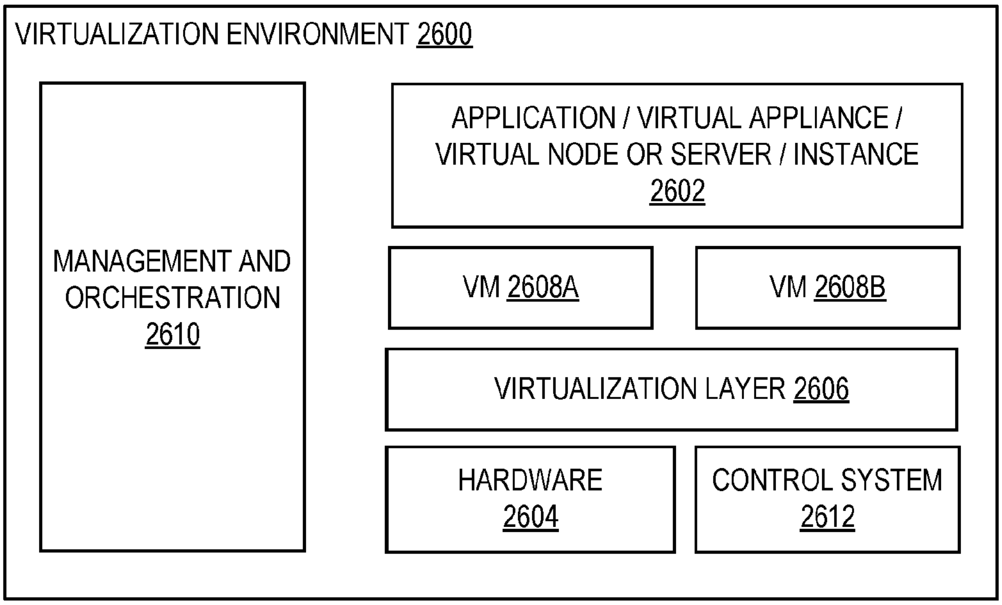

VIRTUALIZATION ENVIRONMENT 2600
MANAGEMENT AND ORCHESTRATION 2610
APPLICATION / VIRTUAL APPLIANCE / VIRTUAL NODE OR SERVER / INSTANCE 2602
VM 2608A
VM 2608B
VIRTUALIZATION LAYER 2606
HARDWARE 2604
CONTROL SYSTEM 2612

FIG. 26

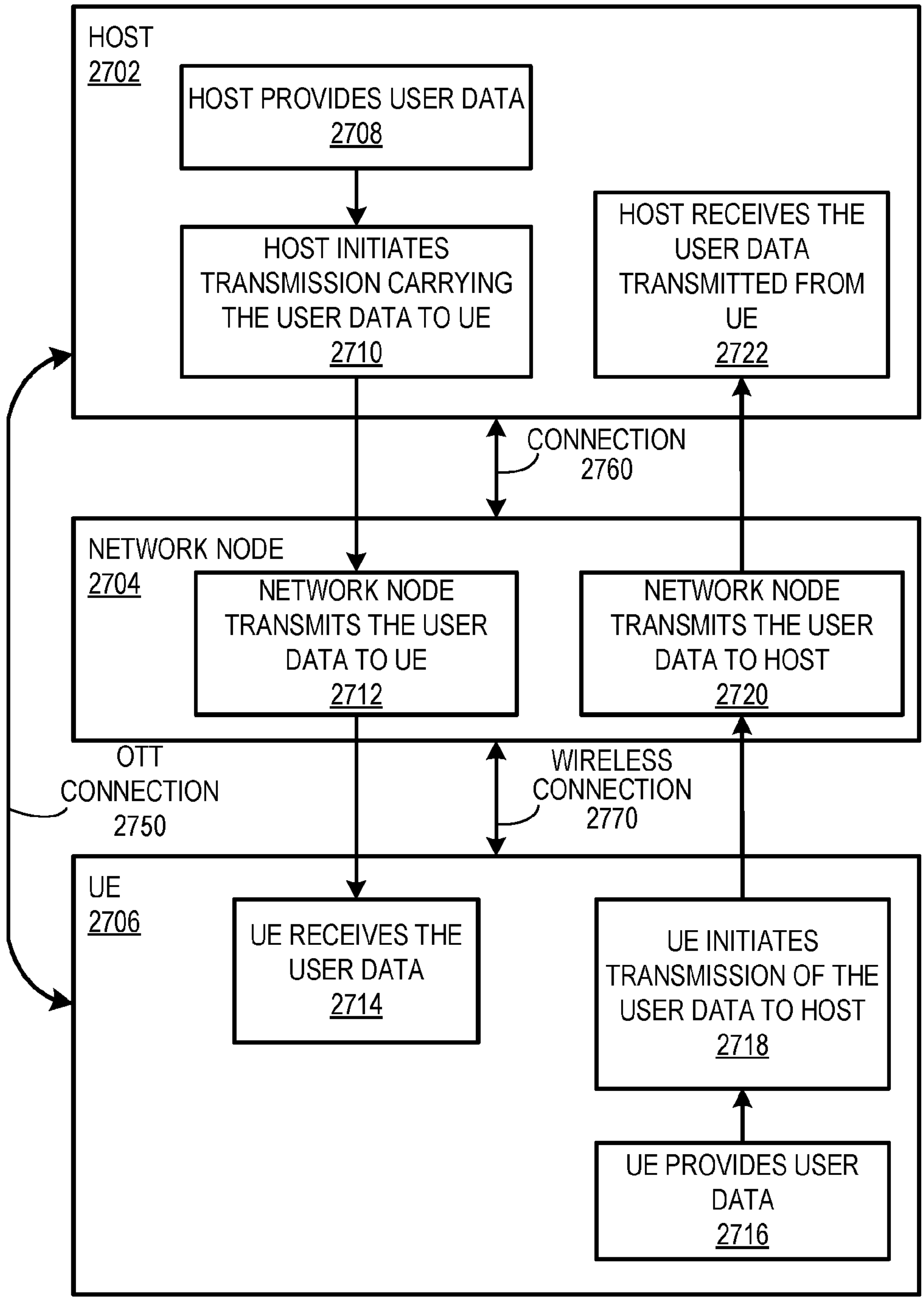

HOST
2702
HOST PROVIDES USER DATA
2708
HOST INITIATES TRANSMISSION CARRYING THE USER DATA TO UE
2710
HOST RECEIVES THE USER DATA TRANSMITTED FROM UE
2722
CONNECTION
2760
NETWORK NODE
2704
NETWORK NODE TRANSMITS THE USER DATA TO UE
2712
NETWORK NODE TRANSMITS THE USER DATA TO HOST
2720
OTT CONNECTION
2750
WIRELESS CONNECTION
2770
UE
2706
UE RECEIVES THE USER DATA
2714
UE INITIATES TRANSMISSION OF THE USER DATA TO HOST
2718
UE PROVIDES USER DATA
2716

FIG. 27

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/061988

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W72/40 H04L5/00
ADD. H04W72/02 H04W72/23

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04L

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

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

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	CMCC: "Discussion on physical channel design framework for sidelink on unlicensed spectrum", 3GPP DRAFT; R1-2204307, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. e-Meeting; 20220509 - 20220520 29 April 2022 (2022-04-29), XP052153470, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/WG1_RL1/TSGR1_109-e/Docs/R1-2204307.zip R1-2204307 - Discussion on physical channel design framework for sidelink on unlincensed spectrum.docx [retrieved on 2022-04-29] the whole document	1-38

[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
14 July 2023	24/07/2023

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	Chimet, Dan

1

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.

1