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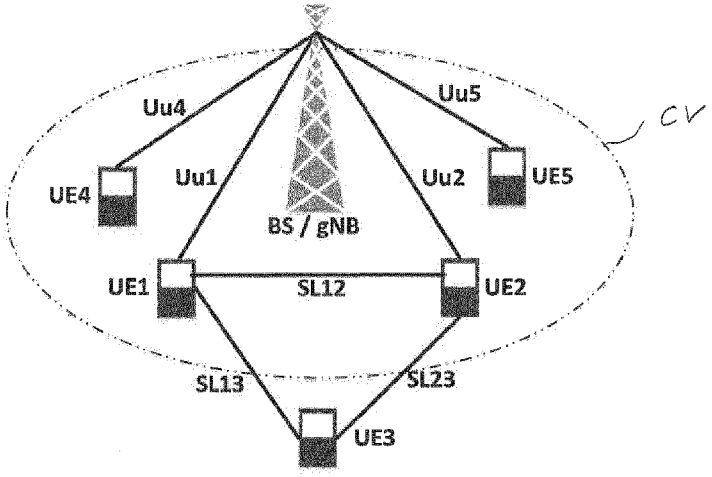

Fig. 5

(57) Abstract: A wireless communication system comprises one or more base stations and a plurality of user devices (UEs), wherein at least some of the UEs are configured for a sidelink communication. The base station and the UEs are configured to communicate according to a slot format obtained from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink (DL) symbols, uplink (UL) symbols, flexible (F) symbols and sidelink (SL) symbols. Wherein at least one of the slot formats for SL communication between UEs includes at least one SL symbol and at least one of the downlink (DL) symbol, the uplink (UL) symbol, and the flexible (F) symbol. Symbols in a slot may have the same or different numerologies. SL symbols may include control information to control subsequent sidelink communication.

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FLEXIBLE SIDELINK COMMUNICATION

Description

The present application relates to the field of wireless communication systems or networks, more specifically to approaches for a wireless sidelink communication among entities of a wireless communication system, in particular between user devices. Embodiments concern enhancements in sidelink communication between user devices. Embodiments provide NR (New Radio) sidelink flexible duplex.

Fig. 1 is a schematic representation of an example of a terrestrial wireless network 100 including, as is shown in Fig. 1(a), a core network 102 and one or more radio access networks RAN_1, RAN_2, ...RAN_N. Fig. 1(b) is a schematic representation of an example of a radio access network RAN_n that may include one or more base stations gNB_1 to gNB_5, each serving a specific area surrounding the base station schematically represented by respective cells 106_1 to 106_5. The base stations are provided to serve users within a cell. The term base station, BS, refers to a gNB in 5G networks, an eNB in UMTS/LTE/LTE-A/ LTE-A Pro, or just a BS in other mobile communication standards. A user may be a stationary device or a mobile device. The wireless communication system may also be accessed by mobile or stationary IoT devices which connect to a base station or to a user. The mobile devices or the IoT devices may include physical devices, ground based vehicles, such as robots or cars, aerial vehicles, such as manned or unmanned aerial vehicles (UAVs), the latter also referred to as drones, buildings and other items or devices having embedded therein electronics, software, sensors, actuators, or the like as well as network connectivity that enables these devices to collect and exchange data across an existing network infrastructure. Fig. 1(b) shows an exemplary view of five cells, however, the RAN_n may include more or less such cells, and RAN_n may also include only one base station. Fig. 1(b) shows two users UE_1 and UE_2, also referred to as user equipment, UE, that are in cell 106_2 and that are served by base station gNB_2. Another user UE_3 is shown in cell 106_4 which is served by base station gNB_4. The arrows 108_1, 108_2 and 108_3 schematically represent uplink/downlink connections for transmitting data from a user UE_1, UE_2 and UE_3 to the base stations gNB_2, gNB_4 or for transmitting data from the base stations gNB_2, gNB_4 to the users UE_1, UE_2, UE_3. Further, Fig. 1(b) shows two IoT devices 110_1 and 110_2 in cell 106_4, which may be stationary or mobile devices. The IoT device 110_1 accesses the wireless communication system via the base station gNB_4 to receive and transmit data as schematically represented by arrow 112_1. The IoT device 110_2 accesses the wireless communication system via the user UE_3 as is schematically represented by arrow 112_2. The respective base station

gNB_1 to gNB_5 may be connected to the core network 102, e.g. via the S1 interface, via respective backhaul links 114_1 to 114_5, which are schematically represented in Fig. 1(b) by the arrows pointing to "core". The core network 102 may be connected to one or more external networks. Further, some or all of the respective base station gNB_1 to gNB_5 may connected, e.g. via the S1 or X2 interface or the XN interface in NR, with each other via respective backhaul links 116_1 to 116_5, which are schematically represented in Fig. 1(b) by the arrows pointing to "gNBs".

For data transmission a physical resource grid may be used. The physical resource grid may comprise a set of resource elements to which various physical channels and physical signals are mapped. For example, the physical channels may include the physical downlink, uplink and sidelink shared channels (PDSCH, PUSCH, PSSCH) carrying user specific data, also referred to as downlink, uplink and sidelink payload data, the physical broadcast channel (PBCH) carrying for example a master information block (MIB) and a system information block (SIB), the physical downlink, uplink and sidelink control channels (PDCCH, PUCCH, PSCCH) carrying for example the downlink control information (DCI), the uplink control information (UCI) and the sidelink control information (SCI). For the uplink, the physical channels may further include the physical random access channel (PRACH or RACH) used by UEs for accessing the network once a UE synchronized and obtained the MIB and SIB. The physical signals may comprise reference signals or symbols (RS), synchronization signals and the like. The resource grid may comprise a frame or radio frame having a certain duration in the time domain and having a given bandwidth in the frequency domain. The frame may have a certain number of subframes of a predefined length, e.g. 1ms. Each subframe may include one or more slots of 12 or 14 OFDM symbols depending on the cyclic prefix (CP) length. A frame may also consist of a smaller number of OFDM symbols, e.g. when utilizing shortened transmission time intervals (sTTI) or a mini-slot/non-slot-based frame structure comprising just a few OFDM symbols.

The wireless communication system may be any single-tone or multicarrier system using frequency-division multiplexing, like the orthogonal frequency-division multiplexing (OFDM) system, the orthogonal frequency-division multiple access (OFDMA) system, or any other IFFT-based signal with or without CP, e.g. DFT-s-OFDM. Other waveforms, like non-orthogonal waveforms for multiple access, e.g. filter-bank multicarrier (FBMC), generalized frequency division multiplexing (GFDM) or universal filtered multi carrier (UFMC), may be used. The wireless communication system may operate, e.g., in accordance with the LTE-Advanced pro standard or the 5G or NR, New Radio, standard.

The wireless network or communication system depicted in Fig. 1 may by a heterogeneous network having distinct overlaid networks, e.g., a network of macro cells with each macro cell including a macro base station, like base station gNB_1 to gNB_5, and a network of small cell base stations (not shown in Fig. 1), like femto or pico base stations.

In addition to the above described terrestrial wireless network also non-terrestrial wireless communication networks exist including spaceborne transceivers, like satellites, and/or airborne transceivers, like unmanned aircraft systems. The non-terrestrial wireless communication network or system may operate in a similar way as the terrestrial system described above with reference to Fig. 1, for example in accordance with the LTE-Advanced Pro standard or the 5G or NR, new radio, standard.

In mobile communication networks, for example in a network like that described above with reference to Fig. 1, like an LTE or 5G/NR network, there may be UEs that communicate directly with each other over one or more sidelink (SL) channels, e.g., using the PC5 interface. UEs that communicate directly with each other over the sidelink may include vehicles communicating directly with other vehicles (V2V communication), vehicles communicating with other entities of the wireless communication network (V2X communication), for example roadside entities, like traffic lights, traffic signs, or pedestrians. Other UEs may not be vehicular related UEs and may comprise any of the above-mentioned devices. Such devices may also communicate directly with each other (D2D communication) using the SL channels.

When considering two UEs directly communicating with each other over the sidelink, both UEs may be served by the same base station so that the base station may provide sidelink resource allocation configuration or assistance for the UEs. For example, both UEs may be within the coverage area of a base station, like one of the base stations depicted in Fig. 1. This is referred to as an "in-coverage" scenario. Another scenario is referred to as an "out-of-coverage" scenario. It is noted that "out-of-coverage" does not mean that the two UEs are not within one of the cells depicted in Fig. 1, rather, it means that these UEs

- may not be connected to a base station, for example, they are not in an RRC connected state, so that the UEs do not receive from the base station any sidelink resource allocation configuration or assistance, and/or
- may be connected to the base station, but, for one or more reasons, the base station may not provide sidelink resource allocation configuration or assistance for the UEs, and/or

- may be connected to the base station that may not support NR V2X services, e.g. GSM, UMTS, LTE base stations.

When considering two UEs directly communicating with each other over the sidelink, e.g. using the PC5 interface, one of the UEs may also be connected with a BS, and may relay information from the BS to the other UE via the sidelink interface. The relaying may be performed in the same frequency band (in-band-relay) or another frequency band (out-of-band relay) may be used. In the first case, communication on the Uu and on the sidelink may be decoupled using different time slots as in time division duplex, TDD, systems.

Fig. 2 is a schematic representation of an in-coverage scenario in which two UEs directly communicating with each other are both connected to a base station. The base station gNB has a coverage area that is schematically represented by the circle 200 which, basically, corresponds to the cell schematically represented in Fig. 1. The UEs directly communicating with each other include a first vehicle 202 and a second vehicle 204 both in the coverage area 200 of the base station gNB. Both vehicles 202, 204 are connected to the base station gNB and, in addition, they are connected directly with each other over the PC5 interface. The scheduling and/or interference management of the V2V traffic is assisted by the gNB via control signaling over the Uu interface, which is the radio interface between the base station and the UEs. In other words, the gNB provides SL resource allocation configuration or assistance for the UEs, and the gNB assigns the resources to be used for the V2V communication over the sidelink. This configuration is also referred to as a Mode 1 configuration in NR V2X or as a Mode 3 configuration in LTE V2X.

Fig. 3 is a schematic representation of an out-of-coverage scenario in which the UEs directly communicating with each other are either not connected to a base station, although they may be physically within a cell of a wireless communication network, or some or all of the UEs directly communicating with each other are to a base station but the base station does not provide for the SL resource allocation configuration or assistance. Three vehicles 206, 208 and 210 are shown directly communicating with each other over a sidelink, e.g., using the PC5 interface. The scheduling and/or interference management of the V2V traffic is based on algorithms implemented between the vehicles. This configuration is also referred to as a Mode 2 configuration in NR V2X or as a Mode 4 configuration in LTE V2X. As mentioned above, the scenario in Fig. 3 which is the out-of-coverage scenario does not necessarily mean that the respective Mode 2 UEs (in NR) or Mode 4 UEs (in LTE) are outside of the coverage 200 of a base station, rather, it means that the respective Mode 2 UEs (in NR) or Mode 4 UEs (in LTE)

are not served by a base station, are not connected to the base station of the coverage area, or are connected to the base station but receive no SL resource allocation configuration or assistance from the base station. Thus, there may be situations in which, within the coverage area 200 shown in Fig. 2, in addition to the NR Mode 1 or LTE Mode 3 UEs 202, 204 also NR Mode 2 or LTE Mode 4 UEs 206, 208, 210 are present.

In the above-described scenarios of vehicular user devices, UEs, a plurality of such user devices may form a user device group, also referred to simply as group, and the communication within the group or among the group members may be performed via the sidelink interfaces between the user devices, like the PC5 interface. For example, the above-described scenarios using vehicular user devices may be employed in the field of the transport industry in which a plurality of vehicles being equipped with vehicular user devices may be grouped together, for example, by a remote driving application. Other use cases in which a plurality of user devices may be grouped together for a sidelink communication among each other include, for example, factory automation and electrical power distribution. In the case of factory automation, a plurality of mobile or stationary machines within a factory may be equipped with user devices and grouped together for a sidelink communication, for example for controlling the operation of the machine, like a motion control of a robot. In the case of electrical power distribution, entities within the power distribution grid may be equipped with respective user devices which, within a certain area of the system may be grouped together so as to communicate via a sidelink communication with each other so as to allow for monitoring the system and for dealing with power distribution grid failures and outages.

Naturally, in the above-mentioned use cases sidelink communication is not limited to a communication within a group. Rather, the sidelink communication may be among any of UEs, like any pair of UEs.

It is noted that the information in the above section is only for enhancing the understanding of the background of the invention and therefore it may contain information that does not form prior art that is already known to a person of ordinary skill in the art.

Starting from systems as described above, there may be a need for improvements or enhancements for sidelink communication among user devices in a wireless communication system.

Embodiments of the present invention are now described in further detail with reference to the accompanying drawings:

Fig. 1 shows a schematic representation of an example of a wireless communication system;

Fig. 2 is a schematic representation of an in-coverage scenario in which UEs directly communicating with each other are connected to a base station;

Fig. 3 is a schematic representation of an out-of-coverage scenario in which UEs directly communicating with each other receive no SL resource allocation configuration or assistance from a base station;

Fig. 4 schematically illustrates a NR flexible slot format;

Fig. 5 is a schematic representation of a wireless communication system including user devices, UEs, capable to perform sidelink communication;

Fig. 6 is a schematic representation of a wireless communication system including a base station and one or more user devices, UEs;

Figures 7 to 14 schematically illustrate examples of different NR slot formats achieved by combining a cell-specific or cell-zone specific slot format with a device-specific or group-specific slot format;

Fig. 15 schematically illustrates an example of slot formats with sidelink symbols of different numerologies;

Fig. 16 schematically illustrates examples of slot configurations to grant transmission to UEs;

Fig. 17 schematically illustrates an example of a handshaking mechanism and an active negotiation pairing between two or more UEs;

Fig. 18 schematically illustrates slot configurations with sidelink symbols of different numerology; and

Fig. 19 illustrates an example of a computer system on which units or modules as well as the steps of the methods described in accordance with the inventive approach may execute.

Before describing embodiments of the invention, it is regarded as being worthwhile to shortly summarize the state of the art of 5G NR with respect to flexible slot formats, and the state of the art for multiplexing SCI switching and data.

State of the Art 5G flexible slot format

5G New Radio has defined a flexible duplex/slot format on the physical layer that facilitates dynamic Time Division Duplex (TDD). According to the technical specification 3GPP TS 38.211, OFDM symbols in a slot can be classified as 'downlink', 'flexible', or 'uplink'. The signaling of slot formats is described in subclause 11.1 of the technical specification 3GPP TS 38.213. Subclause 11.1 of 3GPP TS 38.213 (v.15.2.0) defines possible slot formats in Table 11.1.1-1.

Downlink transmission can only occur in downlink (DL) or flexible symbols, whereas uplink (UL) transmission can only occur in UL or flexible symbols. In case of UEs not capable of full-duplex communications (e.g. UEs operating in TDD mode or FDD (frequency domain duplex) half-duplex mode) guard periods for switching between downlink/receive and uplink/transmit are necessary which are taken from the flexible symbols.

Dynamic TDD in NR is used to dynamically schedule the transmission direction. In case of UEs with half-duplex constraint (e.g. vehicular and sidelink UEs), UEs cannot transmit and receive simultaneously, even on two different frequencies, and therefore the resources between transmit and receive have to be split in time. Dynamic TDD can therefore also be applied for NR sidelink.

Signaling of the slot format in NR can be performed in three ways:

- dynamic scheduling for the scheduled device;
- RRC-based semi-static signaling, e.g. for semi-persistent scheduling (SPS);
- dynamic slot format indication (SFI) for a group of devices.

Any of the three methods or a combination thereof can be used to determine the transmission direction.

In the present disclosure, a downlink symbol in a slot is indicated by the letter "D", an uplink symbol is indicated by the letter "U", and a flexible symbol is indicated by the letter "F" and a sidelink symbol is indicated by the letter "S". A "slot format" is given by the symbols in the slot and by the manner in which the symbols are arranged in the slot. In the present disclosure, a slot or slot format is shown as a number of symbols, typically 14 symbols herein, arranged side by side. In the present disclosure, respective slot formats in the drawings include cell-specific slot formats, device/group specific slot formats and combined slot formats. Throughout the drawings, a cell-specific slot format is indicated by reference sign 10, a device/group specific slot format is indicated by reference sign 12, and a combined slot format is indicated by reference sign 14.

Fig. 4 shows how in 5G NR a cell-specific slot format is combined with a device/group-specific slot format into a combined slot format for UL/DL transmission of a UE. To be more specific, Fig. 4 shows at 10 a cell-specific slot format including a number of flexible symbols F, such as eight flexible symbols, between a number of downlink symbols D, such as three downlink symbols, and a number of uplink symbols U, such as three uplink symbols. As shown at 12 in Fig. 4, a device/group specific slot format includes a different number of flexible symbols F, such as six, arranged between a different number of downlink and uplink symbols, such as four. As shown at 14 in Fig. 4, combination is performed such that symbols classified as 'downlink' (D) or 'uplink' (U) override symbols marked as 'flexible' (F).

State of the art for multiplexing SCI switching and data

According to agreements from RAN1 94, Gothenburg, Sweden, 20th – 24th August 2018, study on multiplexing physical channels considering at least the above aspects should be continued considering the aspects:

- Multiplexing of PSCCH and the associated PSSCH (here, the "associated" means that the PSCCH at least carries information necessary to decode the PSSCH).
    - Study further the following options:
- Option 1: PSCCH and the associated PSSCH are transmitted using non-overlapping time resources.
    - Option 1A: The frequency resources used by the two channels are the same.
    - Option 1B: The frequency resources used by the two channels can be different.
- Option 3: A part of PSCCH and the associated PSSCH are transmitted using overlapping time resources in non-overlapping frequency resources, but another part of the

associated PSSCH and/or another part of the PSCCH are transmitted using non-overlapping time resources.

Technical Problem Statement

Starting with release 16 (Rel-16), NR is being introduced on the sidelink as part of the NR V2X Study Item, see 3GPP RP-181480. In NR as of release 15 (Rel-15), a flexible slot format is only considered for flexible duplexing of uplink and downlink communication. For NR V2X Rel-16 it would be desirable to enhance the flexible slot format to consider also the sidelink for any type of communication: broadcast, multicast and unicast.

The present invention provides improvements or enhancements in a wireless communication among entities of a wireless communication system and, in particular, improvements in flexible sidelink communication between user devices, UEs.

Embodiments of the present invention may be implemented in a wireless communication system as depicted in Fig. 1, Fig. 2, and Fig. 3 including base stations and user devices, user equipment, like mobile terminals or IoT devices.

NR Slot Format Comprising SL Symbol(s) in a Slot

Embodiments of the present invention relate to providing one or more SL symbols in a NR slot format by adding SL symbols in addition to UL, DL, and/or F symbols within a slot.

Embodiments of the present invention provides (see for example claim 1) a wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station and the UEs are configured to communicate according to a slot format obtained from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

The at least one of the slot formats including at least one SL symbol is for sidelink communication between UEs.

In accordance with embodiments (see for example claim 2), for providing a selective assignment of slots as UL, DL, S or F, the wireless communication system is configured to provide the plurality of different slot formats by selectively assigning symbols in a slot for UL, DL, F, or SL.

In accordance with embodiments (see for example claim 3), the plurality of different slot formats are predefined.

In accordance with embodiments (see for example claim 4), one of a predefined combined slot format is used, wherein

the plurality of different slot formats comprises cell-specific, cell-zone-specific, device-specific and group specific slot formats, and

the slot format to be used for the communication is one of a plurality of predefined combined slot formats, a combined slot format being based on a combination of a cell-specific or cell-zone-specific slot format and a device-specific or group specific slot format.

In accordance with embodiments (see for example claim 5), one of a combined slot format is used, which is not predefined and which is obtained by combining cell/device specific formats, wherein

the plurality of different slot formats comprises cell-specific, cell-zone-specific, device-specific and group specific slot formats, and

the slot format to be used for the communication is a combined slot format obtained by combining a cell-specific or cell-zone-specific slot format and a device-specific or group specific slot format.

In accordance with embodiments (see for example claim 6), for combining cell/device specific formats using a preconfigured or base station/network configured rule, the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format are combined according to a certain rule, the certain rule being pre-configured or being set by the base station or the wireless communication system, e.g., dependent on scenario specific or regional communication demands.

In accordance with embodiments (see for example claim 7), when combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format, according to the certain rule:

- slots or symbols classified as DL or UL override slots marked as SL or F, and
- slots or symbols classified as SL override slots marked as F.

In accordance with embodiments (see for example claim 8), when combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format, according to a certain rule:

- slots or symbols classified as SL can override slots or symbols of one or more of a set of either DL, UL or F slots or symbols.

In accordance with embodiments (see for example claim 9), a or the certain rule for combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format is configured via physical layer signaling, such as PDCCH/DCI, PSCCH/SCI, or higher/upper layer signaling, such as RRC, network signaling.

In accordance with embodiments (see for example claim 10), for providing a slot format including only SL symbols, in at least one of the slot formats all symbols are SL symbols.

In accordance with embodiments (see for example claim 11 and Figures 7 to 12), at least one of the slot formats includes at least one DL symbol and/or at least one UL symbol and a F symbols arranged between the at least one SL symbol and the at least one DL symbol and/or the at least one UL symbol.

In accordance with embodiments (see for example claim 12 and Figures 7 to 14), at least one of the slot formats includes a plurality of time consecutive SL symbols, such as a subset of time consecutive SL symbols in a slot, and at least one of a plurality of time consecutive DL

symbols, a plurality of time consecutive UL symbols and a plurality of time consecutive F symbols.

In accordance with embodiments (see for example claim 13 and Figures 13 and 14), at least one of the slot formats includes at least one F symbol and at least one SL symbol.

In accordance with embodiments (see for example claim 14), sidelink resources are mapped to a slot format selected from a plurality of different slot formats, wherein the selected slot format comprises non-contiguous or non-consecutive SL time-domain resources, such as SL symbols or SL slots.

In accordance with embodiments (see for example claim 15), sidelink resources are mapped to a slot format selected from a plurality of different slot formats, wherein the selected slot format comprises contiguous or consecutive SL time-domain resources, such as SL symbols or SL slots.

In accordance with embodiments (see for example claim 16), sidelink resources are composed of one of the said slot formats in time-domain, wherein frequency resources are confined in the time-domain slot formats, wherein the combined time-frequency resources comprise one or more sidelink resource pools.

In accordance with embodiments (see for example claim 17 and Fig. 15), at least one of the slot formats includes at least one SL symbol having a numerology different from a numerology of at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

In accordance with embodiments (see for example claim 18 and Fig. 18), at least one of the slot formats includes at least one first SL symbol and at least one second SL symbol, the first and second SL symbols having different numerologies.

In accordance with embodiments (see for example claim 19 and Figures 16 and 17, at least one of the slot formats includes at least one first SL symbol associated with a first UE and at least one second SL symbol associated with a second UE, wherein, optionally, at least one F symbol is arranged between the first and second SL symbols. In accordance with embodiments (see for example claim 20, the number of symbols for the first UE and the second UE is configured and/or activated and/or deactivated by a base station or the network. In accordance with embodiments (see for example claim 21, either of the first UE and/or the second UE

selects the symbols associated with the first and/or the second UE based on sensing and/or discovery.

In accordance with embodiments (see for example claim 22), the SL symbols include one or more of the following symbols: symbols used for sidelink transmission or sidelink reception, sidelink control, sidelink data, and Automatic Gain Control (AGC), reference symbols, synchronization symbols, slots/symbols used as guard periods or gap for switching between sidelink transmission and sidelink reception.

In accordance with embodiments (see for example claim 23), the wireless communication system is configured to select the slot format dependent on scenario specific or regional communication demands.

In accordance with embodiments (see for example claim 24), at least one of the slot formats depends on a mini-slot or sub-slot of one or more symbols inside a slot. In accordance with embodiments (see for example claim 25), the slot formats are configured via physical layer signaling, such as PDCCH/DCI, PSCCH/SCI, higher layer signaling or network signaling, such as RRC.

In accordance with embodiments (see for example claim 38), the present invention provides a base station for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

> wherein the base station is configured to implement a communication between the base station and the UEs and between the UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and
>
> wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

In accordance with embodiments (see for example claim 39), the present invention provides a user device, UE, for a wireless communication system having one or more base stations and

a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the UE is configured to communicate with the base station and other UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

In accordance with embodiments (see for example claim 43), the present invention provides a method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

by the base station and the UEs, communicating according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

Symbols in a NR Slot Format Having the Same or Different Numerologies

Embodiments of the present invention relate to the provision of symbols in a NR slot format, which have the same or different numerologies.

Embodiments of the present invention provide (see for example claim 26 and Fig. 15), a wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station and the UEs are configured to communicate according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

In accordance with embodiments (see for example claim 27 and Fig. 18), the slot format includes sidelink symbols having at least first and second different numerologies, wherein a UE is configured to

transmit/receive using sidelink symbols having the first numerology,
switch to operating according to the second numerology, and
transmit/receive using sidelink symbols having the second numerology.

In accordance with embodiments (see for example claim 28), the UE is configured to switch to the second numerology at a switching point, which is preconfigured or is defined by a F symbol placed between the SL symbols having the different numerologies, the F symbol having the first numerology or the second numerology.

Embodiments of the present invention (see for example claim 40) provide a base station for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station is configured to implement a communication between the base station and the UEs and between the UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

Embodiments of the present invention (see for example claim 41) provide a user device, UE, for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the UE is configured to communicate with the base station and other UEs to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

Embodiments of the present invention (see for example claim 44) provide a method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

by the base station and the UEs, communicating according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

Indicating New Slot Format by UE

Embodiments of the present invention relate systems and methods in which a new slot format is indicated by a user device, UE.

Embodiments of the present invention (see for example claim 29) provide a wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein
- a first UE is configured to communicate to a second UE over the sidelink communication a slot comprising SL symbols including control information for the

second UE indicating to the second UE a slot format to be used for a subsequent sidelink communication by the second UE, or

- vice versa so that the second UE communicate to the first UE over the sidelink communication a slot comprising SL symbols including control information for the first UE indicating to the first UE a slot format to be used for a subsequent sidelink communication by the first UE.

In accordance with embodiments (see for example claim 30), the control information comprises tail control information, the tail control information comprises one or more of feedback loop information, and/or MCS and TBS, and/or Slot Format Indication (SFI). In accordance with embodiments (see for example claim 31), the feedback loop information comprises at least one of the following: hybrid-automatic retransmission request (HARQ), channel state information (CSI), power control information.

In accordance with embodiments (see for example claim 32 and Fig. 17, cases 3, 4, 5 and 6), the slot format to be used for the subsequent sidelink communication includes at least one first SL symbol associated with a first UE and at least one second SL symbol associated with a second UE, wherein, optionally, at least one F symbol is arranged between the first and second SL symbols.

In accordance with embodiments (see for example claim 33), communication may be bi-directional or non-bidirectional, wherein the first UE is configured to configure and/or assist the second UE with its sidelink communication by signaling to the second UE the slot format via a bi-directional communication between the first UE and the second UE or via a non-bi-directional communication from the first UE.

In accordance with embodiments (see for example claim 34), non-bidirectional communication may be broadcast, groupcast or unicast, wherein the non-bi-directional communication comprises

- a broadcast communication by the first UE so that the second UE receives the slot format via the broadcast, or
- a groupcast communication by the first UE for a group to which the second UE belongs, or
- a unicast communication by the first UE to the second UE.

In accordance with embodiments (see for example claim 35) the communication is bi-directional and the second UE sends data or control information to the first UE.

In accordance with embodiments (see for example claim 36) control information sent from the second UE to the first UE provide a new slot format for the first UE, i.e., the control information send from the second UE to the first UE indicates a slot format to be used by the first UE for a further communication, the further communication including a non-bi-directional communication from the first UE or a further bi-directional communication between the first UE and the second UE.

Embodiments of the present invention (see for example claim 42) provide a user device, UE, for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

> wherein the UE is configured to communicate to another UE over the sidelink communication a slot comprising SL symbols including control information for the other UE indicating to the other UE a slot format to be used for a subsequent sidelink communication by the other UE.

Embodiments of the present invention (see for example claim 43) provide a method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

> by a first UE communicating to a second UE over the sidelink communication a slot comprising SL symbols including control information for the second UE indicating to the second UE a slot format to be used for a subsequent sidelink communication by the second UE.

In the following, embodiments of the present invention will be described in detail using the accompanying drawings. It is to be pointed out that the same elements or elements that have the same functionality are provided with the same or similar reference numbers, and that a repeated description of elements provided with the same or similar reference numbers is typically omitted. Hence, descriptions provided for elements having the same or similar reference numbers are mutually exchangeable. In the following description, a plurality of details is set forth to provide a more thorough explanation of examples of the disclosure.

However, it will be apparent to one skilled it the art that other examples may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form rather than in detail in order to avoid obscuring examples described herein. In addition, features of the different examples described herein may be combined with each other, unless specifically noted otherwise.

Flexible Slot format for NR Sidelink

5G New Radio (NR) as of Release 15 is not supporting sidelink (SL) or device-to-device (D2D) communication between User Equipments (UEs). UEs communicate with a base station (BS), also called gNB, via the Uu interface. Embodiments of this invention is about introducing Sidelink communication in 5G NR.

Fig. 5 shows a schematic representation of a wireless communication system including user devices, UEs, capable to perform sidelink communication. A base station BS/gNB has a coverage indicated by a dashed and dotted line CV. Five UEs UE1, UE2, UE3, UE4 and UE5 are shown. In the examples shown, UE1, UE2 and UE3 are sidelink capable while UE4 and UE5 are not.

In Fig. 5 two UEs UE1 and UE2 are in coverage CV of the BS and are connected to the base station BS via Uu interface Uu1 and Uu2, respectively. UE3 is out-of-coverage and does not have a link via Uu to the base station BS. UE1, UE2 and UE3 are capable of SL communication. Introduction of SL communication for NR requires definition of a SL interface between UEs like the PC5 interface for LTE-based sidelink communications. In Fig. 5, the SL interfaces between UEs are denoted SL12 (UE1-UE2), SL13 (UE1-UE3) and SL23 (UE2-UE3). While shown as different interfaces, the interfaces can be based on the same air interface, e.g. UE1 transmits via the same carrier or air interface to UE2 and UE3, respectively.

In examples, the UEs may be vehicular UEs, pedestrian UEs or roadside units RSU. In examples, the UEs may comprise one or more of a mobile terminal; a stationary terminal; a cellular IoT-UE; a vehicular UE; an IoT or narrowband IoT; NB-IoT device; a ground based vehicle; an aerial vehicle; a drone; a moving base station; a road side unit; a building; and/or any other item or device provided with network connectivity enabling the item/device to communicate using the wireless communication network, e.g., a sensor or actuator. In examples, the base station may comprise one or more of a macro cell base station; a small cell base station; a central unit of a base station; a distributed unit of a base station; a road

side unit; a UE; a remote radio head; an AMF device (AMF = Access and Mobility Management Function); an SMF device (SMF = Session Management Function); a core network entity; a network slice as in the NR or 5G core context, and/or any transmission/reception point, TRP, enabling an item or a device to communicate using the wireless communication network, the item or device being provided with network connectivity to communicate using the wireless communication network.

Fig. 6 is a schematic representation of a wireless communication system including a transmitter 300, like a base station, and one or more receivers 302_1 to 302_n, like user devices, UEs. The transmitter 300 and the receivers 302 may communicate via one or more wireless communication links or channels 304a, 304b, 304c, like a radio link. The transmitter 300 may include one or more antennas ANT_T or an antenna array having a plurality of antenna elements, a signal processor 300a and a transceiver 300b, coupled with each other. The receivers 302 include one or more antennas ANT_R or an antenna array having a plurality of antennas, a signal processor $302a_1$, $302a_n$, and a transceiver $302b_1$, $302b_n$ coupled with each other. The base station 300 and the UEs 302 may communicate via respective first wireless communication links 304a and 304b, like a radio link using the Uu interface, while the UEs 302 may communicate with each other via a second wireless communication link 304c, like a radio link using the PC5 interface. The UEs may communicate with each other over the sidelink. The system, the one or more UEs 302 and the base stations may operate in accordance with the inventive teachings described herein.

When a SL-capable UE is using the same, i.e. shared, carrier or subframe for SL as for Uu, others than SL UEs should not be interfered by SL transmission. In this case, a UE using a shared Uu carrier can use either UL or flexible slots not used by other UEs for sidelink communication (both in receive and transmit direction).

In embodiments of this invention, a new slot/symbol classifier 'sidelink' (S or SL) is introduced in addition to the existing 'downlink' (D or DL), 'flexible' (F or FL), and 'uplink' (U or UL) to classify slots/symbols dedicated for sidelink transmission. Generally, slots/symbols may be regarded as representing examples of time-domain resources. In the present description, examples are described referring to slots having a number of symbols. In other examples, reference is made to slots/symbols, wherein the term slot/symbol is used to either refer to a slot or a symbol. Generally, the teachings herein may be applied to symbols in each slot, such as 14 symbols in each slot in examples. In other examples, the teachings herein may be applied to the slots in a frame or sub-frame.

In examples, side link communication is implemented using at least one format including at least one SL time-domain resource and at least one of a DL time-domain resource, an UL time-domain resource and a flexible time-domain resource. Examples of slot formats are explained referring to respective slot having a number of fourteen symbols. In other examples, each slot may have another number of symbols. In other examples, the time domain resources may be slots in a frame or a sub-frame, wherein each frame or sub-frame comprises a number of slots.

In examples, slot formats may be provided by selectively assigning symbols in a slot for UL, DL, F or SL. In examples, a slot format to be used is obtained by combining a cell-specific or cell-zone specific slot format and a device-specific or group-specific slot format. Examples of how combined slot formats may be achieved are described referring to Figures 7 to 14.

General methods and rules for combination of slots/symbols in the new flexible slot/symbol format may be:

- Slots/symbols classified as 'downlink' (D) or 'uplink' (U) override slots marked as 'sidelink' (S) or 'flexible' (F).
- Slots/symbols classified as 'sidelink' (S) override slots marked as flexible' (F).

Alternatively, the rules to define which type of slot (U, D, F, S) overrides which one can be configured within the network or event per area/base station/cell. This may be useful to give priority depending on scenario specific or regional communication demands, e.g. give preference to sidelink on the Autobahn (highway).

Accordingly, an alternative rule can be configured by a base station or the network, for example, where slots/symbols classified as sidelink (S) can overwrite/override symbols/slots classified as D, U or F. This can be useful, for example, to signal to UEs capable of performing sidelink communication, which symbols/slots are allowed or can be overtaken for sidelink communication.

Sidelink slots/symbols marked as 'S' may embody any types of slots/symbols used for sidelink communication, including but not limited to slots/symbols used for sidelink transmission or sidelink reception, sidelink control, sidelink data, Automatic Gain Control (AGC), reference symbols, synchronization symbols, slots/symbols used as guard periods or gap for switching

between sidelink transmission and sidelink reception. The following sections contain embodiments of this new flexible slot format for NR sidelink.

Shared Carrier or Subframe

In the following embodiments of format combinations for cell-specific and device/group specific slot formats for deployment of NR sidelink communication in a shared carrier or shared subframe for Uu and sidelink are elaborated. In a shared carrier, both cellular UL/DL can operate side-by-side. They could be also multiplexed in time which is the main concern of the embodiments.

In the Figures, time-domain resources in the form of slots, each comprising fourteen symbols are shown. For examples, Fig. 7a) shows a cell-specific slot format 10 having fourteen symbols at first to fourteenth positions. The three symbols at the first to third position of cell-specific slot format 10 are download, D, symbols, the symbols at the fourth to eleventh positions are flexible, F, symbols, and the symbols at the twelfth to fourteenth position are upload, U, symbols. The same nomenclature is used with respect to a device/group specific slot format 12 and a combined slot format 14.

In all the following embodiments the number of slots/symbols for downlink' (D), 'uplink' (U), 'sidelink' (S) or flexible' (F) is only indicative for the shown contiguous fields of downlink, uplink, sidelink or flexible slots/symbols. For instance, Fig. 7a) shows a cell-specific slot/symbol format 10 with three symbols for downlink, D, eight flexible symbols, F, and three symbols for uplink, U, a device/group specific format 12 with three symbols for downlink, D, eight symbols for sidelink, S, and three symbols for uplink, U. It is apparent that any slot/symbol format where at least one slot/symbol of each of the shown contiguous downlink, uplink, sidelink or flexible region is also covered by the embodiment, for instance, a slot format with one downlink, nine flexible and four uplink slots/symbols for the cell-specific format and one downlink, nine sidelink and four uplink slots/symbols for the device/group specific format resulting in one downlink, nine sidelink and four uplink slots/symbols for the combined format. This is true for all examples described.

DL, UL, SL of flexible slots may further depend on the mini-slot (sub-slot) configuration (e.g. 2, 3, 4, or 7 symbols).

In examples, respective combined slot formats are obtained by combining a respective cell-specific (or cell-zone specific) slot format with a respective device specific (or group specific) slot format. In examples, combining may mean that at each position in the slot either the kind of symbol indicated in the cell-specific (or cell-zone specific) slot format or the kind of symbol indicated in the device specific (or group specific) slot format is used. Which kind of symbol is in the combined slot format depends on the rule used to combine the formats, i.e., depends on which kind of symbol overrides the other one. Throughout the specification, cell-specific or cell-zone-specific slot formats are indicated by reference sign 10, device/group specific slot formats are indicated by reference sign 12, and combined slot formats are indicated by reference sign 14.

Different rules may be used in obtaining the combined slot format, wherein the rules may be predefined or may be configured via physical layer signaling, such as PDCCH/DCI, PSCCH/SCI, or higher/upper layer signaling, such as RRC, network signaling.

In Figures 7a) to 7d), embodiments are shown where slots/symbols classified as 'flexible', F, in the cell-specific slot format 10 may be overridden by the device/group-specific configuration with 'sidelink' slots/symbols according to the above defined precedence rules. Switching between slots/symbols of different classifiers, i.e. U, D, S or F, can be performed without a gap between the respective slots/symbols, see Fig. 7a), or otherwise contiguous D, U, and S slots/symbols can be separated by a gap of one or more F slots/symbols, see Fig. 7b). A gap can be used when a guard period is required for switching between the different modes U, D, S or F.

Figures 7a) to 7d) show four examples, in which cell-specific flexible slots/symbols are overridden for S (D, U and S slots/symbols), in which S slots/symbols take precedence over flexible slots/symbols, and/or in which D/U slots/symbols take precedence over S slots/symbols and flexible slots/symbols. According to Fig. 7a), S symbols in slot format 12 override F symbols in slot format 10, wherein no flexible symbols, F, are arranged between D symbols and S symbols or between U symbols and S symbols in the combined format 14. According to Fig. 7b), otherwise, contiguous D, U, and S symbols can be separated by a gap of one or more F symbols, see the combined slot format 14 in Fig. 7b). In examples, a gap can be used when a guard period is required for switching between different modes U, D, S or F. According to Fig. 7c), a device/group specific gap (shown as a flexible symbol F) between D-S and S-U is overridden by cell-specific D/U symbols as can be seen from the combined slot format in Fig. 7c). According to Fig. 7d), cell-specific D symbols and U symbols in cell-specific

slot format 10 take precedence over, i.e. override, S symbols in the device/group specific slot format 12. Thus, the combined slot format 14 in Fig. 7d) comprises a D symbol at the third position and a U symbol at the twelfth position.

Fig. 8a) shows an example of a new slot format where device/group specific D/U symbols take precedence over cell-specific S symbols. This can be seen from combined slot format 14 of Fig. 8a), which comprises a D symbol at the fourth position and a U symbol at the 11 position.

Figures 8b) to 8d) show examples of new slot formats with an alternative precedence rule, in that S slots/symbols take precedence over D/U/F slots/symbols. According to Fig. 8b), D symbols in cell-specific slot format 10 override F symbols in the device/group specific format 12 (the first three positions in combined slot format 14) and S symbols in device/group specific slot format 12 override U symbols in cell-specific slot format 10 (the last three positions in combined slot format 14). According to Fig. 8c), S symbols in device/group specific format 12 override both, F symbols and U symbols in cell-specific slot format 10. According to Fig. 8d), S symbols in device/group specific slot format 12 override D symbols, F symbols and U symbols in cell-specific slot format 10.

Figures 9a) to 9h) show examples with combinations of flexible slot formats where in the resulting slot format (combined slot format 14), D slots/symbols are before the S slots/symbols. As D and S symbols/slots may take precedence over flexible F symbols/slots a gap of one or more F symbols/slots may result where both cell-specific and device/group-specific slots are configured as 'flexible' (Figures 9b), 9d),9f) and 9h)).

According to Fig. 9a), D and S symbols in slot format 10 override F symbols in slot format 12 without a gap/flexible symbol between D and S symbols in combined slot format 14. According to Fig. 9b), D and S symbols in slot format 10 override F symbols in slot format 12 with a gap/flexible symbol F between D and S symbols in combined slot format 14. According to Fig. 9c), D and S symbols in device/group specific slot format 12 override F symbols in cell-specific slot format 10 without a gap/flexible symbol between D and S symbols in combined slot format 14. According to Fig. 9d), D and S symbols in slot format 12 override F symbols in slot format 10 with a gap/flexible symbol F between D and S symbols in combined slot format 14. According to Fig. 9e), D symbols in slot format 10 override F symbols in slot format 12 and S symbols in slot format 12 override F symbols in slot format 10, without a gap/flexible symbol between D and S symbols in combined slot format 14. According to Fig. 9f), D symbols in slot format 10 override F symbols in slot format 12 and S symbols in slot format 12 override F

symbols in slot format 10, with a gap/flexible symbol F between D and S symbols in combined slot format 14. According to Fig. 9g), D symbols in slot format 12 override F symbols in slot format 10 and S symbols in slot format 10 override F symbols in slot format 12, without a gap/flexible symbol between D and S symbols in combined slot format 14. According to Fig. 9h), D symbols in slot format 12 override F symbols in slot format 10 and S symbols in slot format 10 override F symbols in slot format 12, with a gap/flexible symbol F between D and S symbols in combined slot format 14.

Figures 10a) to 10h) show examples with combinations of flexible slot formats where in the resulting slot format (combined slot format 14), S slots/symbols are before to D slots/symbols. As D and S slots/symbols take precedence over flexible slots/symbols a gap of one or more F slots may result where both cell-specific and device/group-specific slots are configured as 'flexible' (Figures 10b), 10d), 10f) and 10h)).

According to Fig. 10a), S and D symbols in slot format 10 override F symbols in slot format 12 without a gap/flexible symbol between S and D symbols in combined slot format 14. According to Fig. 10b), S and D symbols in slot format 10 override F symbols in slot format 12 with a gap/flexible symbol F between S and D symbols in combined slot format 14. According to Fig. 10c), S and D symbols in device/group specific slot format 12 override F symbols in cell-specific slot format 10 without a gap/flexible symbol between S and D symbols in combined slot format 14. According to Fig. 10d), S and D symbols in slot format 12 override F symbols in slot format 10 with a gap/flexible symbol F between S and D symbols in combined slot format 14. According to Fig. 10e), S symbols in slot format 10 override F symbols in slot format 12 and D symbols in slot format 12 override F symbols in slot format 10, without a gap/flexible symbol between S and D symbols in combined slot format 14. According to Fig. 10f), S symbols in slot format 10 override F symbols in slot format 12 and D symbols in slot format 12 override F symbols in slot format 10, with a gap/flexible symbol F between S and D symbols in combined slot format 14. According to Fig. 10g), S symbols in slot format 12 override F symbols in slot format 10 and D symbols in slot format 10 override F symbols in slot format 12, without a gap/flexible symbol between S and D symbols in combined slot format 14. According to Fig. 10h), S symbols in slot format 12 override F symbols in slot format 10 and D symbols in slot format 10 override F symbols in slot format 12, with a gap/flexible symbol F between S and D symbols in combined slot format 14.

Figures 11a) to 11h) shows examples with combinations of flexible slot formats where in the resulting slot format (combined slot format 14), U slots/symbols are before S slots/symbols. As

U and S slots take precedence over flexible slots a gap of one or more F slots results where both cell-specific and device/group-specific slots are configured as 'flexible' (Figures 11b), 11d), 11f) and 11h)).

According to Fig. 11a), U and S symbols in slot format 10 override F symbols in slot format 12 without a gap/flexible symbol between U and S symbols in combined slot format 14. According to Fig. 11b), U and S symbols in slot format 10 override F symbols in slot format 12 with a gap/flexible symbol F between U and S symbols in combined slot format 14. According to Fig. 11c), U and S symbols in device/group specific slot format 12 override F symbols in cell-specific slot format 10 without a gap/flexible symbol between U and S symbols in combined slot format 14. According to Fig. 11d), U and S symbols in slot format 12 override F symbols in slot format 10 with a gap/flexible symbol F between U and S symbols in combined slot format 14. According to Fig. 11e), U symbols in slot format 10 override F symbols in slot format 12 and S symbols in slot format 12 override F symbols in slot format 10, without a gap/flexible symbol between U and S symbols in combined slot format 14. According to Fig. 11f), U symbols in slot format 10 override F symbols in slot format 12 and S symbols in slot format 12 override F symbols in slot format 10, with a gap/flexible symbol F between U and S symbols in combined slot format 14. According to Fig. 11g), U symbols in slot format 12 override F symbols in slot format 10 and S symbols in slot format 10 override F symbols in slot format 12, without a gap/flexible symbol between U and S symbols in combined slot format 14. According to Fig. 11h), U symbols in slot format 12 override F symbols in slot format 10 and S symbols in slot format 10 override F symbols in slot format 12, with a gap/flexible symbol F between U and S symbols in combined slot format 14.

Figures 12a) to 12h) show examples with combinations of flexible slot formats where in the resulting slot format (combined slot format 14) S slots/symbols are before to U slots/symbols. As U and S slots take precedence over flexible slots a gap of one or more F slots results where both cell-specific and device/group-specific slots are configured as 'flexible' (Figures 12b), 12d), 12f) and 12h)).

According to Fig. 12a), S and U symbols in slot format 10 override F symbols in slot format 12 without a gap/flexible symbol between S and U symbols in combined slot format 14. According to Fig. 12b), S and U symbols in slot format 10 override F symbols in slot format 12 with a gap/flexible symbol F between S and U symbols in combined slot format 14. According to Fig. 12c), S and U symbols in device/group specific slot format 12 override F symbols in cell-specific slot format 10 without a gap/flexible symbol between S and U symbols in combined

slot format 14. According to Fig. 12d), S and U symbols in slot format 12 override F symbols in slot format 10 with a gap/flexible symbol F between S and U symbols in combined slot format 14. According to Fig. 12e), S symbols in slot format 10 override F symbols in slot format 12 and U symbols in slot format 12 override F symbols in slot format 10, without a gap/flexible symbol between S and U symbols in combined slot format 14. According to Fig. 12f), S symbols in slot format 10 override F symbols in slot format 12 and U symbols in slot format 12 override F symbols in slot format 10, with a gap/flexible symbol F between S and U symbols in combined slot format 14. According to Fig. 12g), S symbols in slot format 12 override F symbols in slot format 10 and U symbols in slot format 10 override F symbols in slot format 12, without a gap/flexible symbol between S and U symbols in combined slot format 14. According to Fig. 12h), S symbols in slot format 12 override F symbols in slot format 10 and U symbols in slot format 10 override F symbols in slot format 12, with a gap/flexible symbol F between S and U symbols in combined slot format 14.

Shared or dedicated carrier/subframe

In the following embodiments of format combinations for cell-specific and device/group specific slot formats for deployment of NR sidelink communication in a shared or dedicated carrier or subframe for NR sidelink are elaborated. In this section the cell-specific format can also apply for a zone or a cluster.

In all embodiments in this subsection the number of slots/symbols for downlink' (D), 'uplink' (U), 'sidelink' (S) or flexible' (F) is only indicative for the shown contiguous fields of downlink uplink, sidelink or flexible slots/symbols. For instance, in the embodiment of Fig. 13b), a cell-specific slot/symbol format with 12 symbols/slots for sidelink and 2 flexible symbols/slots is shown. It is apparent that any slot/symbol format where at least one slot/symbol of each of the shown contiguous downlink, uplink, sidelink or flexible region is also covered by the embodiment, for instance, a slot format with 10 slots for sidelink and 4 flexible slots.

DL, UL, SL or flexible slots may further depend on the mini-slot (sub-slot) configuration (e.g. 2, 3, 4, or 7 symbols).

Figures 13a) to 13e) show embodiments of a cell-specific symbol/slot configuration or format 10, where symbols/slots are classified as 'sidelink' S or 'flexible' F only, and a device/group-specific configuration or format 12, with flexible slots/symbols only. The resulting slot formats (combined slot formats 14) can have S transmission over all slots/symbols, Fig. 13a), the first

slots/symbols only with F slots/symbols at the end, Fig. 13b), the last slots/symbols only with F slots/symbols at the beginning, fig. 13c), F slots at the begin and the end with SL slots in the middle, Fig. 13d), or S slots/symbols at the begin and end with F slots in the middle, Fig. 13e).

Figures 14a) to 14e) show embodiments of a device/group-specific configuration or format 12, where symbols/slots are classified as 'sidelink' S or 'flexible' F only, and a cell-specific configuration or format 10, with flexible slots/symbols only. The resulting slot formats (combined slot formats 14) can have S transmission over all slots/symbols, Fig. 14a), the first slots/symbols only with F slots/symbols at the end, Fig. 14b), the last slots/symbols only with F slots/symbols at the beginning, Fig. 14c), F slots at begin and end with SL slots in the middle, Fig. 14d), or SL slots at the begin and end with F slots in the middle, Fig. 14 e).

Thus, in examples, there is at least one slot format in which all symbols/slots are S symbols/slots or in which all symbols/slots are S symbols/slots and F symbols/slots.

Different Numerologies

In embodiments of the present invention, UEs are configured to communicate according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, wherein all symbols in the slot have the same numerology, or at least some of the symbols in the slot have different numerologies. In examples, UEs able for sidelink communication using slot formats as described above may also be able to communicate using such slots having the same or different numerologies. In other examples, such different numerologies may be independent on the above described different slot formats including at least one SL symbol.

Thus, in further embodiments, and in addition or as s a variant of the above description, flexible slots may run different numerologies, such as subcarrier spacing, SCS, and Cyclic Prefix, CP, length, especially when overridden by sidelink communication. Fig. 15 depicts a case in which flexible symbols/slots (overridden by sidelink symbols/slots) are operating in different numerologies. Fig. 15 shows a slot format 30 comprising four D symbols, six F symbols and four U symbols. The symbols have a unified numerology. The configuration may be similar to the configuration of the cell-specific slot format showing in Fig. 7a). A possible slot format 32, such as a combined slot format, in which two F symbols of slot format 30 are replaced by S symbols is shown at 32. According to slot format 32, the same numerology 1 is used for all symbols, i.e. the S symbols have the same numerology as the remaining symbols of the slot,

such as the same SCS of X kHz. In examples, the numerology of the S symbols may be different from the numerology of other symbols of the slot. At 34 in Fig. 15 a slot format is shown, in which the S symbols have a different numerology 2, such as a SCS of 2X kHz.

In slot formats 32 and 34, a gap of two flexible symbols, F, is provided between D symbols and S symbols and between S symbols and U symbols, respectively. In other examples, a gap of a different length may be provided. Slot format 36 comprises a gap of one F symbol in connection with S symbols having the same numerology 1 as other symbols, and slot format 38 comprises a gap of one F symbol in connection with S symbols having a different numerology when compared to other symbols of the slot.

In embodiments, the system may be to use a numerology, such as a sub carrier spacing of 2^k *15 kHz, where k = 0, 1, 2, ..., for S symbols, which may be different from the Uu (forward and reverse link between the base-station and the UE). As an example, the Uu can operate on 30 kHz whereas the SL can be 15, 30, or 60 kHz.

Thus, in embodiments of the present invention, user devices, UEs, of a wireless communication system, may be to communicate using S symbols having a different numerology when compared to symbols used for communication with a base station, for example. Thus, embodiments of the present invention provide an increased flexibility in sidelink communication between UEs. In embodiments, a UE may be to transmit and receive sidelink symbols having a first numerology and to transmit and receive sidelink symbols having a second numerology different from the first numerology. In embodiments, the UE may be to switch between the first and second numerology, i.e. is operating according to the first numerology, then switches to the second numerology and is then operating according to the second numerology or vice versa. In embodiments, switching may take place at a gap, such as a flexible symbol, between S symbols having different numerologies. Thus, embodiments permit UL/UL and SL multiplexing with multiple numerologies, such as SCSs.

Embodiments of the present invention permit symbols of different numerologies to be used in a single slot independent of whether the slot includes S symbols or not. Thus, embodiment provide an increased flexibility for other communications in a wireless communication network even in case the corresponding slot does not use sidelink communication.

NR SL Bi-Directional Communication

In embodiments of the present invention, a wireless communication system, a base station and/or a user device may be adapted for bi-directional communication. Bidirectional communication may be unicast and multicast/groupcast. In such embodiments, after a discovery phase, on sidelink resources, the UE may send a transmission and receive a transmission as a response to its own prior transmission or a new transmission. In this case, the destination ID is required in each communication direction.

Embodiments provide a wireless communication system, comprising: one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication. A first UE is configured to communicate to a second UE over the sidelink communication a slot comprising SL symbols including control information for the second UE indicating to the second UE a slot format to be used for a subsequent sidelink communication by the second UE, or vice versa so that the second UE communicate to the first UE over the sidelink communication a slot comprising SL symbols including control information for the first UE indicating to the first UE a slot format to be used for a subsequent sidelink communication by the first UE.

NR SL Bi-Directional Communication without handshaking

Fig. 16 shows SL slot configuration for granting transmission between a pair of UEs in the same slot. In Fig. 16, four different configurations are depicted for two UEs, namely UE1 and UE2, switching their transmission alternatively. Those two UEs may be communicating to each other or to different receivers. During the period when UE1 is transmitting all other UEs in the group or UE2 (if unicast is maintained) are in receive (RX) mode. Switching between UE1 to UE2 may require leaving one (or more) of the flexible slots as a time gap, i.e., depending on the direction of the communication itself. In slot 40, six F symbols are left as a time gap, in slot 42, four F symbols are left as a time gap, in slot 44, two F symbols are left as a time gap, and in slot 46, one F symbol is left as a time gap.

The configuration for switching transmission between UEs may be controlled in the following ways:

- It may be up to the base-station and/or the network to allocate mini-slot (non-slot base) for UEs in the same 14-symbol slot;
- It may be up to the base-station and/or the network to activate and deactivate the configuration (if it is a semi-persistence scheduling, SPS, or configured grants for grant free transmission);

- It may be up to the network or upper-layers to allocate pairs into a 14-symbol slot (as in Fig. 16) where UE1 is paired to UE2, i.e., after a successful discovery;
- It may be up to the UEs to sense and discover empty mini-slots if non-slot-based sensing (and a short-term sensing mechanism) is configured.

Both UE1 and UE2 may skip their grants or their sensed-free subslots after transmission is successful or after a radio link failure.

NR SL Bi-Directional Communication with handshaking

In examples, the communication network and/or the UEs may be adapted to implement a handshaking mechanism and an active negotiating pairing between two or more UEs. Slot configurations that may be used in such approaches are shown in Fig. 17. Fig. 17 shows examples of slot configurations or formats that can be used in a handshaking mechanism as a variant of the pairing splits shown in Fig. 16.

To be more specific, Fig 17 shows six cases of how distributions of symbols in slots may look like.

According to case 1, all symbols in a slot are for data transmission by UE1. According to case 2, twelve symbols are for a data transmission by UE1 and the last two symbols 60 are for a transmission of control information from UE1 to UE2. In examples, the control information may indicate to UE2 a slot format to be used for a subsequent sidelink communication. According to case 3, a gap, such as in the form of a flexible symbol F, is provided between eleven symbols for data transmission by UE1 and two symbols 62 for a transmission of control information from UE1 to UE2. According to case 4, a slot may include symbols 64 for a data transmission by UE1, symbols 66 for a transmission of control information by UE1, and symbols 68 for a transmission of control information by UE2. A gap, such as in the form of a flexible symbol, may be provided between the control information sent by different UEs. According to case 5, a slot may include symbols 70 for a data transmission from UE1, symbols 72 for a transmission of control information by UE2, and symbols 74 for a transmission of data by UE2. Symbols 70 for data transmission may be separated from symbols 72 by a gap, such as in the form if a flexible symbol. Finally, according to case 6, a slot may comprise symbols 70 for a transmission of data by UE1, symbols 60 for a transmission of control information by UE1, symbols 72 for a transmission of control information by UE2 and symbols 74 for a transmission of data by UE2.

Embodiments of the present invention permit time resources to be distributed in a flexible manner. It goes without saying that the examples in Fig. 17 are examples and that other examples may have a different distribution of symbols in a slot.

In examples, the control information may comprise tail control information comprising one or more of feedback loop information, MCS, TBS, and a slot format indication. In examples, the control information may request feedback, such as an acknowledgment signal, Ack, a negative acknowledgement signal, Nack, more data or switching-grants. In examples, symbols 60, 66, 68, and 72 may be for a transmission of control information requesting feedback. In examples, feedback loop information of the control information may include at least one of the following: hybrid-automatic retransmission request (HARQ), channel state information (CSI), power control information.

In this operation, one UE, UE1 in the example shown, may be allocated (or succeeded to have sensed free slots) to one or more of fourteen symbol slots. After a successful discovery or pairing possibility, UE1 transmits a complete frame as in case 1.

Later, the operation can be as follows:

- Case 1: UE1 sends an all data 14-symbol slot over sidelink communication (S symbols only)
- Case 2: UE1 transmits to another UE in the group or in the proximity (even when it is broadcasting) and sends sidelink control information, SCI, multiplexed in time (back loaded as in Fig. 17 for UE1 or front loaded if possible) using non-overlapping time resources or overlapping time resources. This control information might be:
    - Specific for a certain UE (say UE2 if it is known from pairing or discovery process), hence, it is only for UE2.
    - If the discovery process does not have a specific UE or pairing is not a target, then the control information is non specific UE.
    - Tail Control information (which might also be front loaded or back loaded) might contain:
        - Feedback loop information
        - MCS (modulation coding scheme) and TBS (transport block size)
        - Slot-frame indication (SFI) with a new (or modified) SCI with SFI_XX_RNTI, this includes the slot-frame configuration of the next slot/slots, i.e., whether dynamic or preconfigured, XX is for instance denoting sidelink, V2X etc.
- Case 3: UE2 might send all data (2-symbol slot) frame; so do UE1

- Case 4: UE1 sends another control information (new or adapted/modified SCI format with SFI_XX_ RNTI) with new SFI configuration. The new SFI may allow UE2 to send more data this time.
- Case 5: UE2 (with front loaded control symbols – or also back-loaded if possible) send more data with a new SFI switching SCI for UE1.
- Case 6: represents a homogeneous and steady operation (e.g., equal traffic load) where the resources are split between two or more UEs with SCI either front or back loaded (as in the figure).

Thus, in examples, the slot format to be used for the a subsequent sidelink communication includes at least one first SL symbol associated with a first UE and at least one second SL symbol associated with a second UE, wherein, optionally, at least one F symbol is arranged between the first and second SL symbols. In examples, the first UE is configured to configure and/or assist the second UE with its sidelink communication by signaling to the second UE the slot format via a bi-directional communication between the first UE and the second UE or via a non-bi-directional communication from the first UE. In examples, a non-bi-directional communication comprises a broadcast communication by the first UE so that the second UE receives the slot format via the broadcast, or a groupcast communication by the first UE for a group to which the second UE belongs, or a unicast communication by the first UE to the second UE. In examples, in case of a bi-directional communication between the first UE and the second UE, the second UE is configured to send to the first UE data or control information. In examples, the control information sent from the second UE to the first UE indicates a slot format to be used by the first UE for a further communication, the further communication including a non-bi-directional communication from the first UE or a further bi-directional communication between the first UE and the second UE.

Resource Pool definitions with Flexible Duplexing with Different Numerology

In embodiments of the present disclosure, it is allowed for the base-station or the network to configure two or more resource pools (with sub-indexing, or sub-bit-maps (old terminology)). Assuming the bit mapping for sidelink is seen as 0101101..., i.e., "0" is for cellular configuration only and "1" sidelink configuration (may be shared). On the top of the bit mapping/indexing, the base-station can define a sub-mapping or sub-indexing:

- to allocate two or more different resource pools simultaneously, where all symbols are having the same numerology (e.g., same subcarrier spacing and Cyclic prefix (CP) length);

- to allocate two or more different resource pools simultaneously, where each pool has a unique numerology but different from one resource pool to another, i.e., the first symbols-pool has numerology 30 and the second has 60 kHz subcarrier spacing.
- between each pool, where there could be a configured gap symbol used as a flexible symbol (i.e., could be overridden by SL). This gap symbol or F symbol might have numerology of the first symbols pool or the second symbols pool.

Fig. 18 show three examples of slots defining two resource pools configured with similar or different numerologies. The number of configured pools can also be more than two. The flexible symbol between the two (or more) pools can be configured like the previous pool numerology or the following pool numerology. The flexible slot/symbol can be left as a gap or can be overridden.

To be more specific, Fig. 18 shows at 80 a slot having two resource pools 82 and 84 of sidelink symbols S having the same numerology and separated by a flexible symbol F. Each resource pools may be for a different UE. Fig. 18 shows at 86 a slot having two resource pools 82 and 88, which have different numerologies and which are separated by a symbol F having the first numerology resulting in a wider gap. Fig. 18 shows at 90 a slot having two resource pools 82 and 92, which have different numerologies and which are separated by a symbol F having the second numerology resulting in a narrower gap.

Thus, in examples, sidelink resources may be composed of one of the said slot formats in time-domain, wherein frequency resources may be confined in the time-domain slot formats, wherein the combined time-frequency resources comprise one or more sidelink resource pools.

The effect of adding flexible duplex to the sidelink is to be able to grant the required resources more flexible depending on the current need. The resource pool management will enhance for NR sidelink for any type of communication: broadcast, multicast and unicast.

Examples of the invention can be used for V2X communications based on the 5G New Radio (NR) waveform as well as other communications based on NR sidelink, e.g. Device-to-Device communications (D2D). Further possible use cases: URLLC, critical communication, ProSe. A technical application area for sidelink communication is visualized in Figures 1 to 3 and 5.

Embodiments described above may be applied to vehicles being either in a connected mode, also referred to as mode 1 or mode 3 configuration, or vehicles being in the idle/autonomous mode, also referred to as mode 2 or mode 4 configuration. However, the present invention is not limited to V2V communications or V2X communications, rather it is also applicable to any device-to-device communications, for example non-vehicular mobile users or stationary users that perform a sidelink communication, e.g., over the PC5 interface. Also in such scenarios, the inventive aspects described above may be employed.

In accordance with embodiments, the wireless communication system may include a terrestrial network, or a non-terrestrial network, or networks or segments of networks using as a receiver an airborne vehicle or a spaceborne vehicle, or a combination thereof.

In accordance with embodiments, a receiver may comprise one or more of a mobile or stationary terminal, an IoT device, a ground based vehicle, an aerial vehicle, a drone, a building, or any other item or device provided with network connectivity enabling the item/device to communicate using the wireless communication system, like a sensor or actuator. In accordance with embodiments, a transmitter may comprise one or more of a macro cell base station, or a small cell base station, or a spaceborne vehicle, like a satellite or a space, or an airborne vehicle, like a unmanned aircraft system (UAS), e.g., a tethered UAS, a lighter than air UAS (LTA), a heavier than air UAS (HTA) and a high altitude UAS platforms (HAPs), or any transmission/reception point (TRP) enabling an item or a device provided with network connectivity to communicate using the wireless communication system.

Although some aspects of the described concept have been described in the context of an apparatus, it is clear that these aspects also represent a description of the corresponding method, where a block or a device corresponds to a method step or a feature of a method step. Analogously, aspects described in the context of a method step also represent a description of a corresponding block or item or feature of a corresponding apparatus.

Various elements and features of the present invention may be implemented in hardware using analog and/or digital circuits, in software, through the execution of instructions by one or more general purpose or special-purpose processors, or as a combination of hardware and software. For example, embodiments of the present invention may be implemented in the environment of a computer system or another processing system. Fig. 19 illustrates an example of a computer system 500.

The units or modules as well as the steps of the methods performed by these units may execute on one or more computer systems 500. The computer system 500 includes one or more processors 502, like a special purpose or a general purpose digital signal processor. The processor 502 is connected to a communication infrastructure 604, like a bus or a network. The computer system 500 includes a main memory 506, e.g., a random access memory (RAM), and a secondary memory 508, e.g., a hard disk drive and/or a removable storage drive. The secondary memory 508 may allow computer programs or other instructions to be loaded into the computer system 500. The computer system 500 may further include a communications interface 510 to allow software and data to be transferred between computer system 500 and external devices. The communication may be in the form of electronic, electromagnetic, optical, or other signals capable of being handled by a communications interface. The communication may use a wire or a cable, fiber optics, a phone line, a cellular phone link, an RF link and other communications channels 512.

The terms "computer program medium" and "computer readable medium" are used to generally refer to tangible storage media such as removable storage units or a hard disk installed in a hard disk drive. These computer program products are means for providing software to the computer system 500. The computer programs, also referred to as computer control logic, are stored in main memory 506 and/or secondary memory 508. Computer programs may also be received via the communications interface 510. The computer program, when executed, enables the computer system 500 to implement the present invention. In particular, the computer program, when executed, enables processor 502 to implement the processes of the present invention, such as any of the methods described herein. Accordingly, such a computer program may represent a controller of the computer system 500. Where the disclosure is implemented using software, the software may be stored in a computer program product and loaded into computer system 500 using a removable storage drive, an interface, like communications interface 510.

The implementation in hardware or in software may be performed using a digital storage medium, for example cloud storage, a floppy disk, a DVD, a Blue-Ray, a CD, a ROM, a PROM, an EPROM, an EEPROM or a FLASH memory, having electronically readable control signals stored thereon, which cooperate (or are capable of cooperating) with a programmable computer system such that the respective method is performed. Therefore, the digital storage medium may be computer readable.

Some embodiments according to the invention comprise a data carrier having electronically readable control signals, which are capable of cooperating with a programmable computer system, such that one of the methods described herein is performed.

Generally, embodiments of the present invention may be implemented as a computer program product with a program code, the program code being operative for performing one of the methods when the computer program product runs on a computer. The program code may for example be stored on a machine-readable carrier.

Other embodiments comprise the computer program for performing one of the methods described herein, stored on a machine-readable carrier. In other words, an embodiment of the inventive method is, therefore, a computer program having a program code for performing one of the methods described herein, when the computer program runs on a computer.

A further embodiment of the inventive methods is, therefore, a data carrier (or a digital storage medium, or a computer-readable medium) comprising, recorded thereon, the computer program for performing one of the methods described herein. A further embodiment of the inventive method is, therefore, a data stream or a sequence of signals representing the computer program for performing one of the methods described herein. The data stream or the sequence of signals may for example be configured to be transferred via a data communication connection, for example via the Internet. A further embodiment comprises a processing means, for example a computer, or a programmable logic device, configured to or adapted to perform one of the methods described herein. A further embodiment comprises a computer having installed thereon the computer program for performing one of the methods described herein.

In some embodiments, a programmable logic device (for example a field programmable gate array) may be used to perform some or all of the functionalities of the methods described herein. In some embodiments, a field programmable gate array may cooperate with a microprocessor in order to perform one of the methods described herein. Generally, the methods are preferably performed by any hardware apparatus.

The above described embodiments are merely illustrative for the principles of the present invention. It is understood that modifications and variations of the arrangements and the details described herein are apparent to others skilled in the art. It is the intent, therefore, to be limited

only by the scope of the impending patent claims and not by the specific details presented by way of description and explanation of the embodiments herein.

References/ Abbreviations

Reference	Details
3GPP TS 38.211 v. 15.2.0	NR, physical channels and modulation
3GPP TS 38.213 v. 15.2.0	NR, physical layer procedures for control
3GPP RP-181480	"New SID: Study on NR V2X", RAN#80, La Jolla

Abbreviation	Meaning
NR	New Radio
SL	Sidelink
V2X	Vehicle to Everything
SCI	Sideling Control Information
D2D	Device to Device

CLAIMS

1. A wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station and the UEs are configured to communicate according to a slot format obtained from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

2. The wireless communication system of claim 1, wherein the wireless communication system is configured to provide the plurality of different slot formats by selectively assigning symbols in a slot for UL, DL, F, or SL.

3. The wireless communication system of claim 1 or 2, wherein the plurality of different slot formats are predefined.

4. The wireless communication system of claim 1 or 2, wherein

the plurality of different slot formats comprises cell-specific, cell-zone-specific, device-specific and group specific slot formats, and

the slot format to be used for the communication is one of a plurality of predefined combined slot formats, a combined slot format being based on a combination of a cell-specific or cell-zone-specific slot format and a device-specific or group specific slot format.

5. The wireless communication system of claim 1 or 2, wherein

the plurality of different slot formats comprises cell-specific, cell-zone-specific, device-specific and group specific slot formats, and

the slot format to be used for the communication is a combined slot format obtained by combining a cell-specific or cell-zone-specific slot format and a device-specific or group specific slot format.

6. The wireless communication system of claim 5, wherein the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format are combined according to a certain rule, the certain rule being pre-configured or being set by the base station or the wireless communication system, e.g., dependent on scenario specific or regional communication demands.

7. The wireless communication system of claim 6, wherein, when combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format, according to the certain rule:
   - slots or symbols classified as DL or UL override slots marked as SL or F, and
   - slots or symbols classified as SL override slots marked as F.

8. The wireless communication system of claim 6, wherein, when combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format, according to a certain rule:
   - slots or symbols classified as SL can override slots or symbols of one or more of a set of either DL, UL or F slots or symbols.

9. The wireless communication system of one of claims 5 to 8, wherein a or the certain rule for combining the cell-specific/cell-zone-specific slot format and the device-specific/group specific slot format is configured via physical layer signaling, such as PDCCH/DCI, PSCCH/SCI, or higher/upper layer signaling, such as RRC, network signaling.

10. The wireless communication system of any one of the preceding claims, wherein in at least one of the slot formats all symbols are SL symbols.

11. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes at least one DL symbol and/or at least one UL symbol and a F symbol arranged between the at least one SL symbol and the at least one DL symbol and/or the at least one UL symbol.

12. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes a plurality of a subset of time consecutive SL symbols in a slot and at least one of a plurality of time consecutive DL symbols, a plurality of time consecutive UL symbols and a plurality of time consecutive F symbols.

13. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes at least one F symbol and at least one SL symbol.

14. The wireless communication system of any of the preceding claims, wherein sidelink resources are mapped to a slot format selected from a plurality of different slot formats, wherein the selected slot format comprises non-contiguous or non-consecutive SL time-domain resources, such as SL symbols or SL slots.

15. The wireless communication system of any of claims 1 to 13, wherein the sidelink resources are mapped to a slot format selected from a plurality of different slot formats, wherein the selected slot format comprises contiguous or consecutive SL time-domain resources, such as SL symbols or SL slots.

16. The wireless communication system of any of the preceding claims, wherein sidelink resources are composed of one of the said slot formats in time-domain, wherein frequency resources are confined in the time-domain slot formats, wherein the combined time-frequency resources comprise one or more sidelink resource pools.

17. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes at least one SL symbol having a numerology different from a numerology of at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

18. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes at least one first SL symbol and at least one second SL symbol, the first and second SL symbols having different numerologies.

19. The wireless communication system of any one of the preceding claims, wherein at least one of the slot formats includes at least one first SL symbol associated with a first UE

and at least one second SL symbol associated with a second UE, wherein, optionally, at least one F symbol is arranged between the first and second SL symbols.

20. The wireless communication system of claim 19, wherein the number of symbols for the first UE and the second UE is configured and/or activated and/or deactivated by a base station or the network.

21. The wireless communication system of claim 19 or 20, wherein either of the first UE and/or the second UE selects the symbols associated with the first and/or the second UE based on sensing and/or discovery.

22. The wireless communication system of any one of the preceding claims, wherein the SL symbols include one or more of the following symbols: symbols used for sidelink transmission or sidelink reception, sidelink control, sidelink data, and Automatic Gain Control (AGC), reference symbols, synchronization symbols, slots/symbols used as guard periods or gap for switching between sidelink transmission and sidelink reception.

23. The wireless communication system of any one of the preceding claims, wherein the wireless communication system is configured to select the slot format dependent on scenario specific or regional communication demands.

24. The wireless communication system of any of the preceding claims, wherein at least one of the slot formats depends on a mini-slot or sub-slot of one or more symbols inside a slot.

25. The wireless communication system of any of the preceding claims, wherein the slot formats are configured via physical layer signaling, such as PDCCH/DCI, PSCCH/SCI, higher layer signaling or network signaling, such as RRC.

26. A wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station and the UEs are configured to communicate according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

27. The wireless communication system of claim 26, wherein the slot format includes sidelink symbols having at least first and second different numerologies, wherein a UE is configured to

transmit/receive using sidelink symbols having the first numerology,
switch to operating according to the second numerology, and
transmit/receive using sidelink symbols having the second numerology.

28. The wireless communication system of claim 27, wherein the UE is configured to switch to the second numerology at a switching point, which is preconfigured or is defined by a F symbol placed between the SL symbols having the different numerologies, the F symbol having the first numerology or the second numerology.

29. A wireless communication system, comprising:

one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein
- a first UE is configured to communicate to a second UE over the sidelink communication a slot comprising SL symbols including control information for the second UE indicating to the second UE a slot format to be used for a subsequent sidelink communication by the second UE, or
- vice versa so that the second UE communicate to the first UE over the sidelink communication a slot comprising SL symbols including control information for the first UE indicating to the first UE a slot format to be used for a subsequent sidelink communication by the first UE.

30. The wireless communication system of claim 29, wherein the control information comprises tail control information, the tail control information comprising one or more of feedback loop information, and/or MCS and TBS, and/or Slot Format Indication (SFI).

31. The wireless communication system of claim 29 or 30, wherein the feedback loop information comprises at least one of the following: hybrid-automatic retransmission request (HARQ), channel state information (CSI), power control information.

32. The wireless communication system of one of claims 29 to 31, wherein the slot format to be used for the subsequent sidelink communication includes at least one first SL symbol associated with a first UE and at least one second SL symbol associated with a second UE, wherein, optionally, at least one F symbol is arranged between the first and second SL symbols.

33. The wireless communication system of one of claims 29 to 32, wherein the first UE is configured to configure and/or assist the second UE with its sidelink communication by signaling to the second UE the slot format via a bi-directional communication between the first UE and the second UE or via a non-bi-directional communication from the first UE.

34. The wireless communication system of claim 33, a non-bi-directional communication comprises
- a broadcast communication by the first UE so that the second UE receives the slot format via the broadcast, or
- a groupcast communication by the first UE for a group to which the second UE belongs, or
- a unicast communication by the first UE to the second UE.

35. The wireless communication system of any one of claims 29 to 34, wherein, in case of a bi-directional communication between the first UE and the second UE, the second UE is configured to send to the first UE data or control information.

36. The wireless communication system of claim 35, wherein the control information sent from the second UE to the first UE indicates a slot format to be used by the first UE for a further communication, the further communication including a non-bi-directional

communication from the first UE or a further bi-directional communication between the first UE and the second UE.

37. The wireless communication system of any one of the preceding claims, wherein

the UE comprises one or more of

- a mobile terminal, or
- stationary terminal, or
- cellular IoT-UE, or
- vehicular UE, or
- an IoT or narrowband IoT, NB-IoT, device, or
- a ground based vehicle, or
- an aerial vehicle, or
- a drone, or
- a moving base station, or
- road side unit, or
- a building, or
- any other item or device provided with network connectivity enabling the item/device to communicate using the wireless communication network, e.g., a sensor or actuator, and

wherein the base station comprises one or more of

- a macro cell base station, or
- a small cell base station, or
- a central unit of a base station, or
- a distributed unit of a base station, or
- a road side unit, or
- a UE, or
- a remote radio head, or
- an AMF, or
- an SMF, or
- a core network entity, or
- a network slice as in the NR or 5G core context, or
- any transmission/reception point, TRP, enabling an item or a device to communicate using the wireless communication network, the item or device being

provided with network connectivity to communicate using the wireless communication network.

38. A base station for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station is configured to implement a communication between the base station and the UEs and between the UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

39. A user device, UE, for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the UE is configured to communicate with the base station and other UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

40. A base station for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the base station is configured to implement a communication between the base station and the UEs and between the UEs according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

41. A user device, UE, for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the UE is configured to communicate with the base station and other UEs to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

42. A user device, UE, for a wireless communication system having one or more base stations and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication,

wherein the UE is configured to communicate to another UE over the sidelink communication a slot comprising SL symbols including control information for the other UE indicating to the other UE a slot format to be used for a subsequent sidelink communication by the other UE.

43. A method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

by the base station and the UEs, communicating according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols selected from downlink, DL, symbols, uplink, UL, symbols, flexible, F, symbols and sidelink, SL, symbols, and

wherein at least one of the slot formats includes at least one SL symbol and at least one of the downlink, DL, symbol, the uplink, UL, symbol, and the flexible, F, symbol.

44. A method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

by the base station and the UEs, communicating according to a slot format selected from a plurality of different slot formats, each slot format defining in a slot a number of symbols, and

wherein
all symbols in the slot have the same numerology, or
at least some of the symbols in the slot have different numerologies.

45. A method in a wireless communication system having one or more base stations, and a plurality of user devices, UEs, at least some of the UEs configured for a sidelink communication, the method comprising

by a first UE communicating to a second UE over the sidelink communication a slot comprising SL symbols including control information for the second UE indicating to the second UE a slot format to be used for a subsequent sidelink communication by the second UE.

46. A non-transitory computer program product comprising a computer readable medium storing instructions which, when executed on a computer, perform the method of any one of claims 43 to 45.

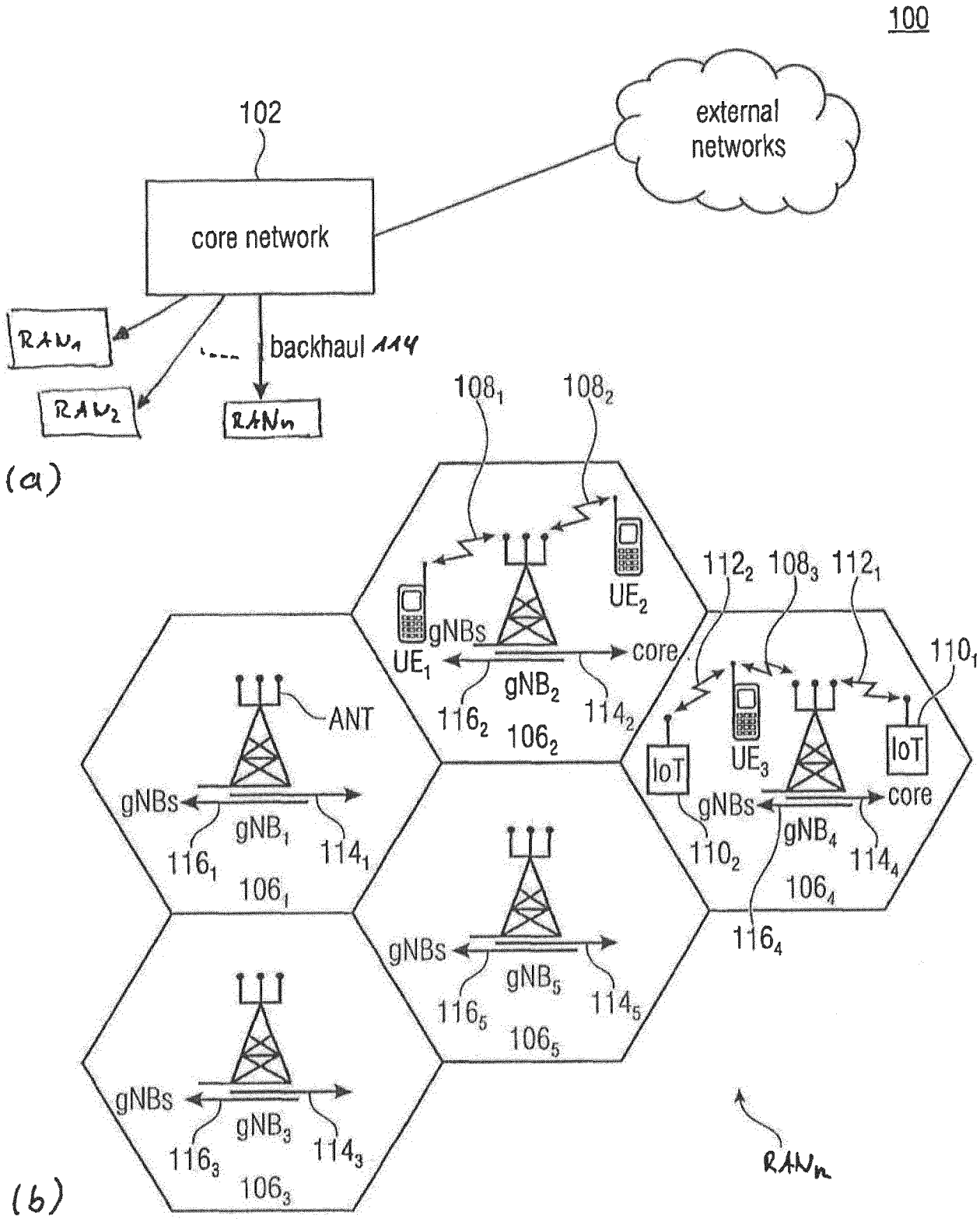
100
102
external networks
core network
RAN1
RAN2
RANn
backhaul 114
(a)
108_1
108_2
112_2
108_3
112_1
110_1
UE2
gNBs
UE1
core
gNB2
116_2
106_2
114_2
ANT
gNBs
gNB1
116_1
106_1
114_1
IoT
UE3
IoT
gNBs
core
110_2
gNB4
114_4
106_4
116_4
gNBs
gNB5
116_5
106_5
114_5
gNBs
gNB3
116_3
106_3
114_3
RANn
(b)

Fig. 1

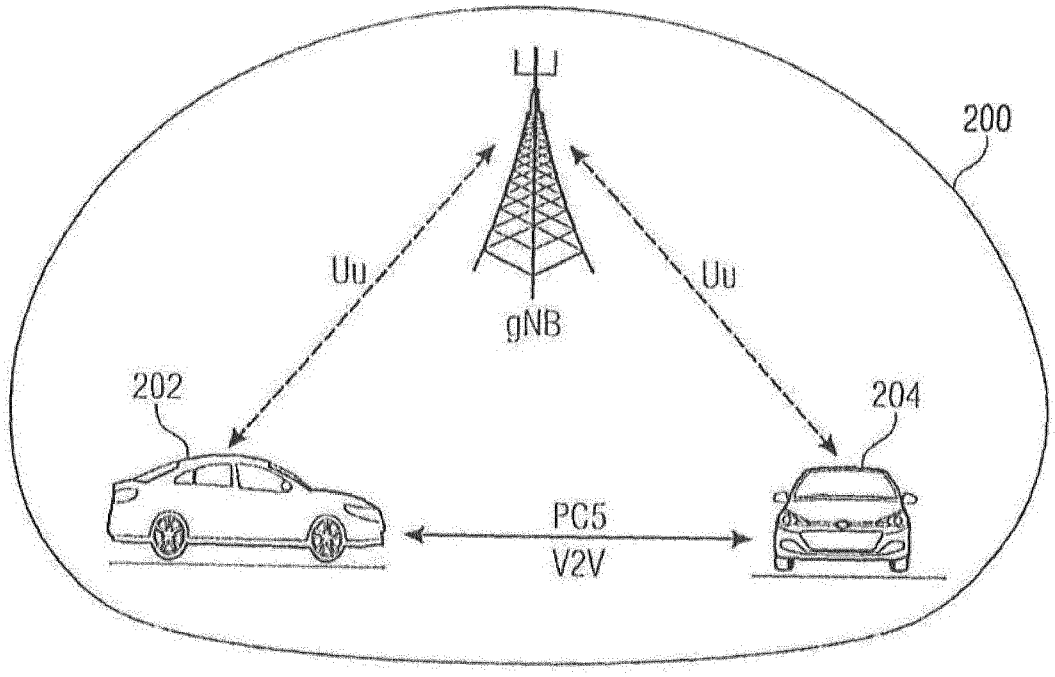

Fig. 2

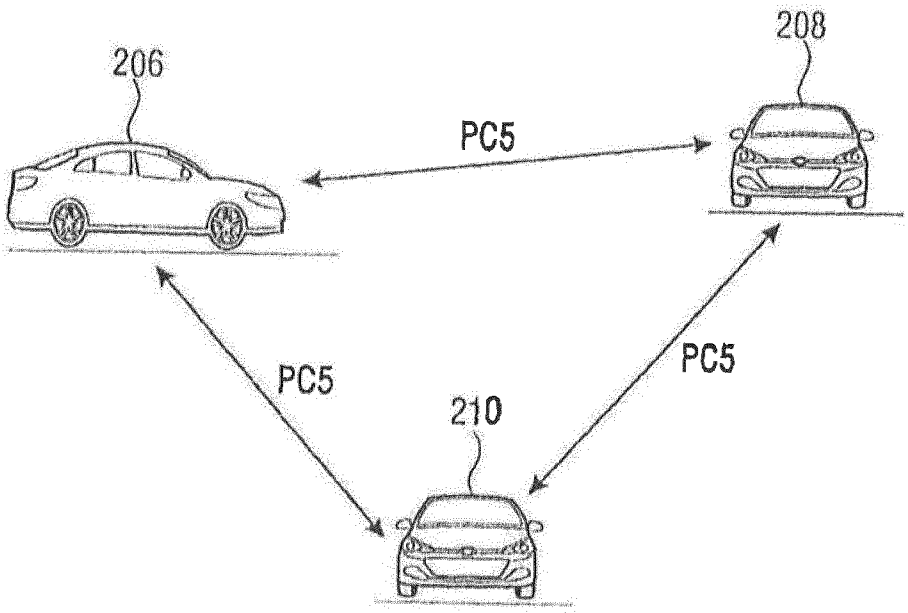

Fig. 3

NR Slot format: DL, flexible and UL slots/symbols; NO SL slots/symbols														
Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U
Device/group specific slot format	D	D	D	D	F	F	F	F	F	F	U	U	U	U
Combined slot format	D	D	D	D	F	F	F	F	F	F	U	U	U	U

10
12
14

Fig. 4

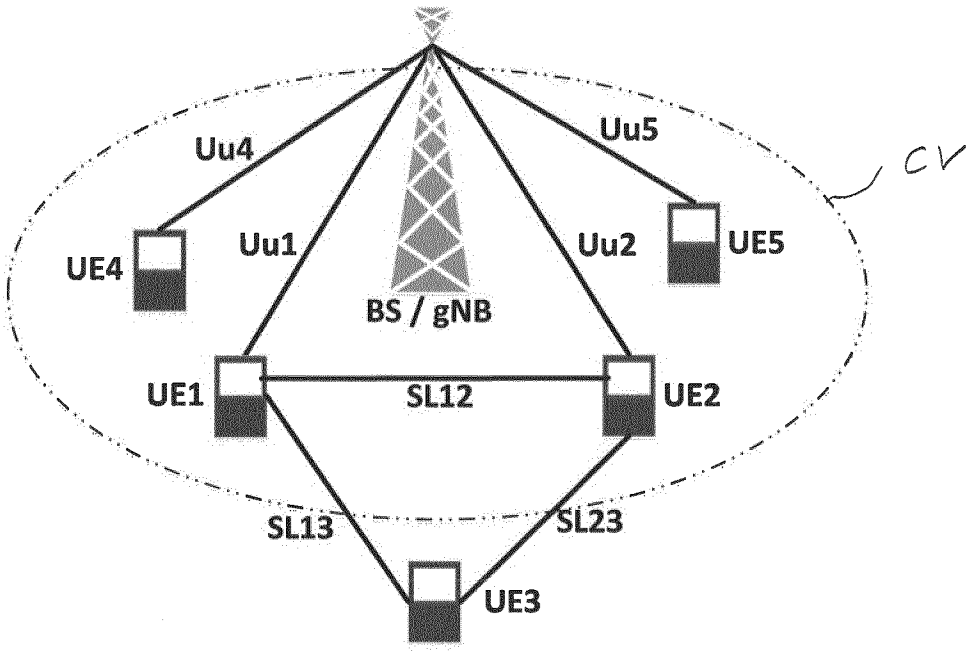

Fig. 5

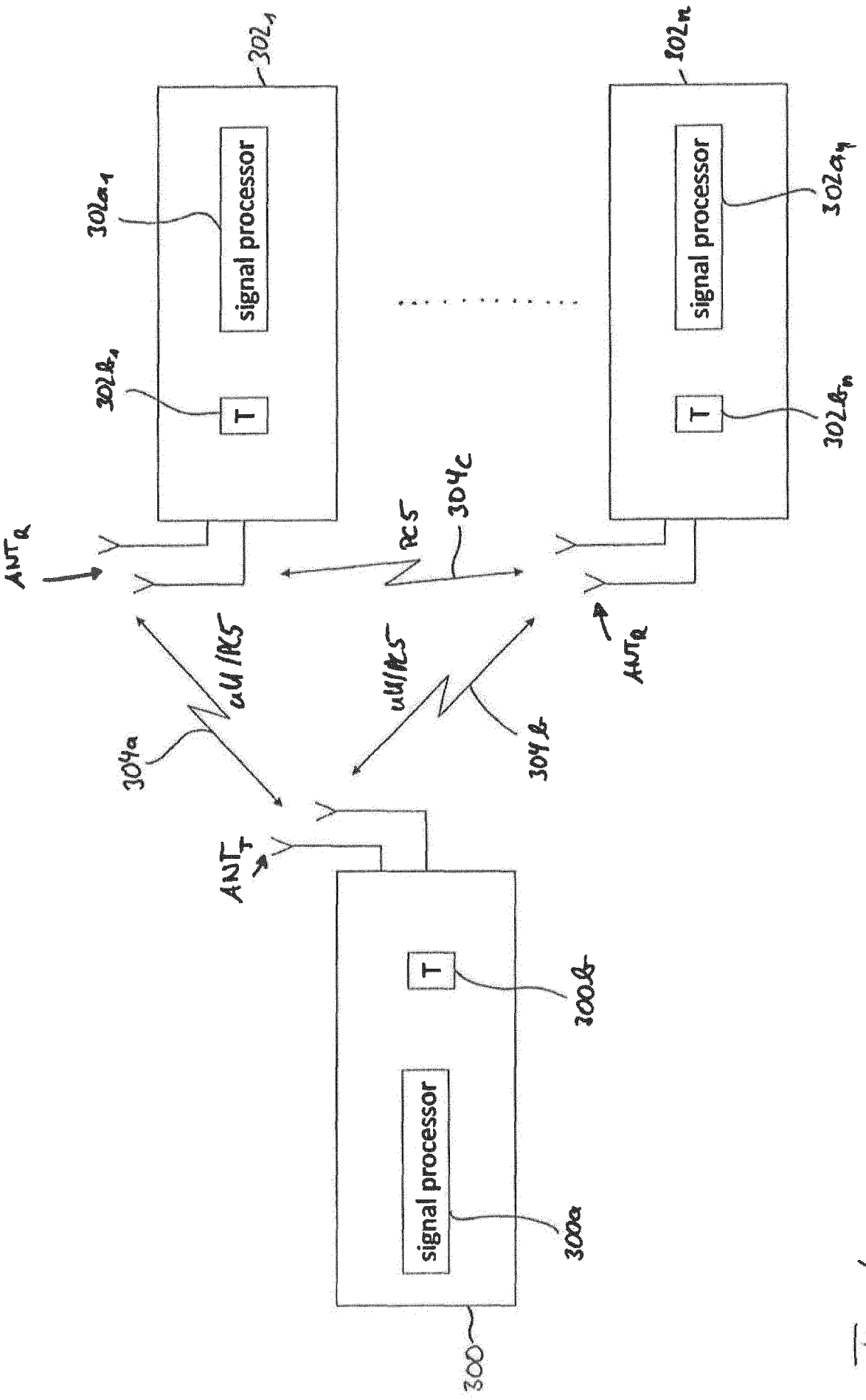
signal processor
T
signal processor
T
signal processor
T
302_1
$302a_1$
$302b_1$
302_n
$302a_n$
$302b_n$
ANT_R
RS
304c
ANT_R
UL/RS
304a
UL/RS
304b
ANT_T
300b
300a
300

Fig. 6

1. Cell-specific flexible slots/symbols overridden for SL (DL, UL and SL slots/symbols)
SL slots/symbols take precedence over flexible slots/symbols
DL/UL slots/symbols take precedence over SL slots/symbols and flexible slots/symbols

a) all flexible slots/symbols overridden by SL slots/symbols

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	10
Device/group specific slot format	D	D	D	S	S	S	S	S	S	S	S	U	U	U	12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	U	U	U	14

b) some flexible slots/symbols overridden by SL slots/symbols, gap between DL-SL and SL-UL

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	10
Device/group specific slot format	D	D	D	F	S	S	S	S	S	S	F	U	U	U	12
Combined slot format	D	D	D	F	S	S	S	S	S	S	F	U	U	U	14

c) device/group specific gap between DL-SL and SL-UL is overridden by cell-specific DL/UL slots/symbols

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	10
Device/group specific slot format	D	D	F	S	S	S	S	S	S	S	S	F	U	U	12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	U	U	U	14

d) cell-specific DL/UL slots/symbols take precedence over SL slots/symbols

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	10
Device/group specific slot format	D	D	S	S	S	S	S	S	S	S	S	S	U	U	12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	U	U	U	14

Fig. 7

2. device/group specific DL/UL slots/symbols take precedence over SL slots/symbols															
a) Cell-specific slot format	D	D	D	S	S	S	S	S	S	S	S	U	U	U	~10
Device/group specific slot format	D	D	D	D	S	S	S	S	S	S	U	U	U	U	~12
Combined slot format	D	D	D	D	S	S	S	S	S	S	U	U	U	U	~14

Alternative rule: SL slots/symbols take precedence over DL/UL slots/symbols															
b) **a) UL slots/symbols overwritten by SL slots/symbols**															
Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	S	S	S	~12
Combined slot format	D	D	D	F	F	F	F	F	F	F	F	S	S	S	~14
c) **b) UL and F slots/symbols overwritten by SL slots/symbols**															
Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	~10
Device/group specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~14
d) **c) DL, UL and F slots/symbols overwritten by SL slots/symbols**															
Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	U	U	U	~10
Device/group specific slot format	F	F	S	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	S	S	S	S	S	S	S	S	S	S	S	S	~14

Fig. 8

3. Flexible slot formats resulting in combined DL before SL slots/symbols (potential gap/flexible symbols between DL and SL, no UL)

a) Cell-specific DL/SL config, device/group specific all flexible slots/symbols

Cell-specific slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~14

b) Cell-specific DL/SL config, device/group specific all flexible slots/symbols, gap between DL and SL

Cell-specific slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~14

c) device/group-specific DL/SL config, cell-specific all flexible slots/symbols

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~14

d) device/group-specific DL/SL config, cell-specific all flexible slots/symbols, , gap between DL and SL

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~14

e) Cell-specific DL before device/group-specific SL

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~14

f) Cell-specific DL before device/group-specific SL, gap between DL and SL

Cell-specific slot format	D	D	D	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	F	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~14

g) device/group-specific DL before cell-specific SL

Cell-specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	D	D	D	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	D	D	D	S	S	S	S	S	S	S	S	S	S	S	~14

h) device/group-specific DL before cell-specific SL, gap between DL and SL

Cell-specific slot format	F	F	F	F	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	D	D	D	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	D	D	D	F	S	S	S	S	S	S	S	S	S	S	~14

Fig. 9

4. Formats resulting in combined SL before DL slots/symbols
(potential gap/flexible symbols between SL and DL, no UL)

a) Cell-specific DL/SL config, device/group specific all flexible slots/symbols

Cell-specific slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~14

b) Cell-specific DL/SL config, device/group specific all flexible slots/symbols, gap between SL and DL

Cell-specific slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~14

c) device/group-specific DL/SL config, cell-specific all flexible slots/symbols

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~12
Combined slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~14

d) device/group-specific DL/SL config, cell-specific all flexible slots/symbols, gap between SL and DL

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~12
Combined slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~14

e) Cell-specific SL before device/group-specific DL

Cell-specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	D	D	D	D	D	D	D	D	D	D	D	~12
Combined slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~14

f) Cell-specific SL before device/group-specific DL, gap between SL and DL

Cell-specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	F	D	D	D	D	D	D	D	D	D	D	~12
Combined slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~14

g) device/group-specific SL before cell-specific DL

Cell-specific slot format	F	F	F	D	D	D	D	D	D	D	D	D	D	D	~10
Device/group specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	D	D	D	D	D	D	D	D	D	D	D	~14

h) device/group-specific SL before cell-specific DL, gap between SL and DL

Cell-specific slot format	F	F	F	F	D	D	D	D	D	D	D	D	D	D	~10
Device/group specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	F	D	D	D	D	D	D	D	D	D	D	~14

Fig. 10

5. Flexible slot formats resulting in combined UL before SL slots/symbols (potential gap/flexible symbols between UL and SL, no DL)

a) Cell-specific UL/SL config, device/group specific all flexible slots/symbols

Cell-specific slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~14

b) Cell-specific UL/SL config, device/group specific all flexible slots/symbols, gap between UL and SL

Cell-specific slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~14

c) device/group-specific UL/SL config, cell-specific all flexible slots/symbols

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~14

d) device/group-specific UL/SL config, cell-specific all flexible slots/symbols, , gap between UL and SL

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~14

e) Cell-specific UL before device/group-specific SL

Cell-specific slot format	U	U	U	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~14

f) Cell-specific UL before device/group-specific SL, gap between UL and SL

Cell-specific slot format	U	U	U	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	F	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~14

g) device/group-specific UL before cell-specific SL

Cell-specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	U	U	U	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	U	U	U	S	S	S	S	S	S	S	S	S	S	S	~14

h) device/group-specific UL before cell-specific SL, gap between UL and SL

Cell-specific slot format	F	F	F	F	S	S	S	S	S	S	S	S	S	S	~10
Device/group specific slot format	U	U	U	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	U	U	U	F	S	S	S	S	S	S	S	S	S	S	~14

Fig. 11

6. Formats resulting in combined SL before UL slots/symbols
(potential gap/flexible symbols between SL and UL, no DL)

a) Cell-specific UL/SL config, device/group specific all flexible slots/symbols

Cell-specific slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~14

b) Cell-specific UL/SL config, device/group specific all flexible slots/symbols, gap between SL and UL

Cell-specific slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~10
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~14

c) device/group-specific UL/SL config, cell-specific all flexible slots/symbols

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~12
Combined slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~14

d) device/group-specific UL/SL config, cell-specific all flexible slots/symbols, gap between SL and UL

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~12
Combined slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~14

e) Cell-specific SL before device/group-specific UL

Cell-specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	U	U	U	U	U	U	U	U	U	U	U	~12
Combined slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~14

f) Cell-specific SL before device/group-specific UL, gap between SL and UL

Cell-specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	F	U	U	U	U	U	U	U	U	U	U	~12
Combined slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~14

g) device/group-specific SL before cell-specific UL

Cell-specific slot format	F	F	F	U	U	U	U	U	U	U	U	U	U	U	~10
Device/group specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	U	U	U	U	U	U	U	U	U	U	U	~14

h) device/group-specific SL before cell-specific UL, gap between SL and UL

Cell-specific slot format	F	F	F	F	U	U	U	U	U	U	U	U	U	U	~10
Device/group specific slot format	S	S	S	F	F	F	F	F	F	F	F	F	F	F	~12
Combined slot format	S	S	S	F	U	U	U	U	U	U	U	U	U	U	~14

Fig. 12

7. Cell/zone/cluster-specifc SL and flexible slots/symbols only, device/group-specific flexible slots/symbols only SL slots/symbols take precedence over flexible slots/symbols

a) Cell-specific SL only slots/symbols

Cell-specific slot format	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Combined slot format	S	S	S	S	S	S	S	S	S	S	S	S	S	S

b) Cell-specific SL and flexible slots/symbols; flexible slots/symbols at end

Cell-specific slot format	S	S	S	S	S	S	S	S	S	S	S	S	F	F
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Combined slot format	S	S	S	S	S	S	S	S	S	S	S	S	F	F

c) Cell-specific SL and flexible slots/symbols; flexible slots/symbols at beginning

Cell-specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Combined slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S

d) Cell-specific SL and flexible slots/symbols; flexible slots/symbols at beginning and end

Cell-specific slot format	F	F	F	S	S	S	S	S	S	S	S	F	F	F
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Combined slot format	F	F	F	S	S	S	S	S	S	S	S	F	F	F

e) Cell-specific SL and flexible slots/symbols; flexible slots/symbols in the middle

Cell-specific slot format	S	S	S	F	F	F	F	F	F	F	F	S	S	S
Device/group specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F
Combined slot format	S	S	S	F	F	F	F	F	F	F	F	S	S	S

Fig. 13

8. Device/group-specifc SL and flexible slots/symbols only, cell/zone/cluster-specific flexible slots/symbols only SL slots/symbols take precedence over flexible slots/symbols

a) Device/group-specific SL only slots/symbols

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	S	S	S	S	S	S	S	S	S	S	S	S	S	S	~14

b) Device/group-specific SL and flexible slots/symbols; flexible slots/symbols at end

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	S	S	S	S	S	S	S	S	S	F	F	~12
Combined slot format	S	S	S	S	S	S	S	S	S	S	S	S	F	F	~14

c) Device/group-specific SL and flexible slots/symbols; flexible slots/symbols at beginning

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~12
Combined slot format	F	F	F	S	S	S	S	S	S	S	S	S	S	S	~14

d) Device/group-specific SL and flexible slots/symbols; flexible slots/symbols at beginning and end

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	F	F	F	S	S	S	S	S	S	S	S	F	F	F	~12
Combined slot format	F	F	F	S	S	S	S	S	S	S	S	F	F	F	~14

e) Device/group-specific SL and flexible slots/symbols; flexible slots/symbols in the middle

Cell-specific slot format	F	F	F	F	F	F	F	F	F	F	F	F	F	F	~10
Device/group specific slot format	S	S	S	F	F	F	F	F	F	F	F	S	S	S	~12
Combined slot format	S	S	S	F	F	F	F	F	F	F	F	S	S	S	~14

Fig. 14

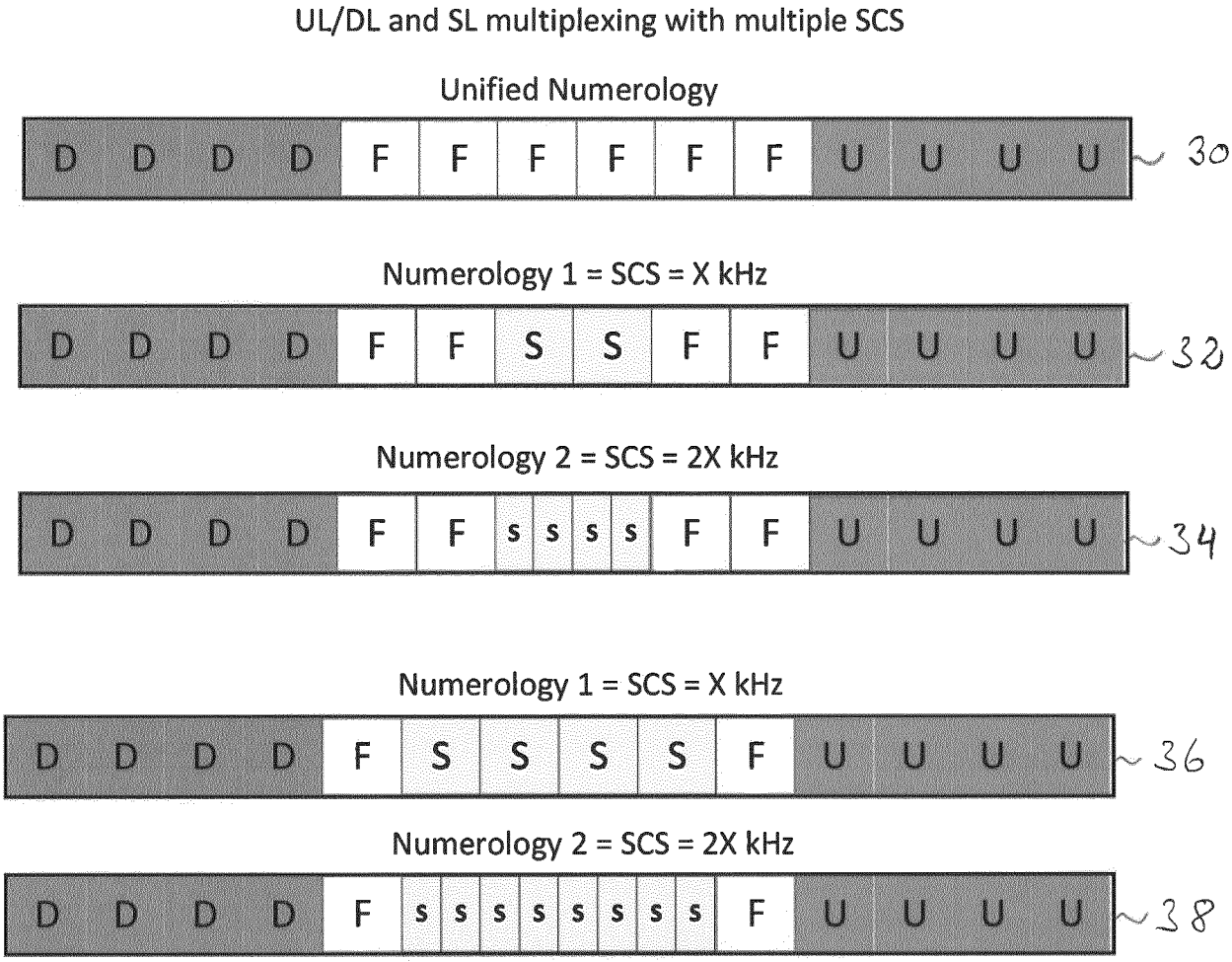
UL/DL and SL multiplexing with multiple SCS
Unified Numerology
D D D D F F F F F F U U U U
30
Numerology 1 = SCS = X kHz
D D D D F F S S F F U U U U
32
Numerology 2 = SCS = 2X kHz
D D D D F F s s s s F F U U U U
34
Numerology 1 = SCS = X kHz
D D D D F S S S S F U U U U
36
Numerology 2 = SCS = 2X kHz
D D D D F s s s s s s s s F U U U U
38

Fig. 15

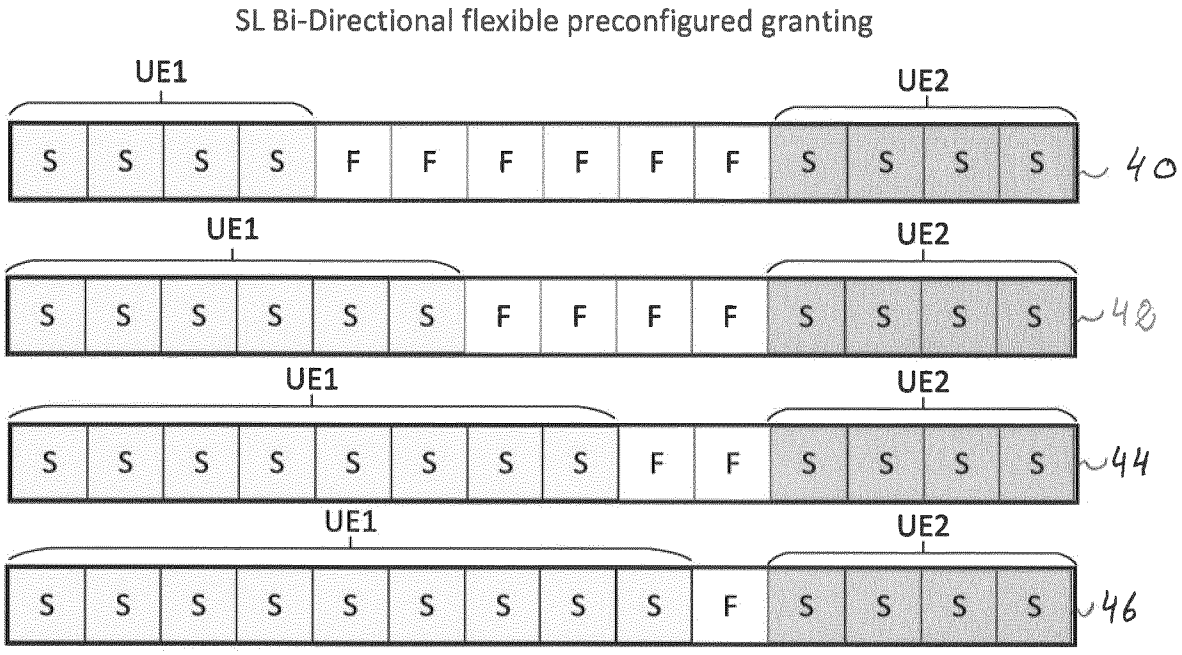
SL Bi-Directional flexible preconfigured granting
UE1
UE2
S S S S F F F F F F S S S S
40
UE1
UE2
S S S S S S F F F F S S S S
48
UE1
UE2
S S S S S S S S F F S S S S
44
UE1
UE2
S S S S S S S S S F S S S S
46

Fig. 16

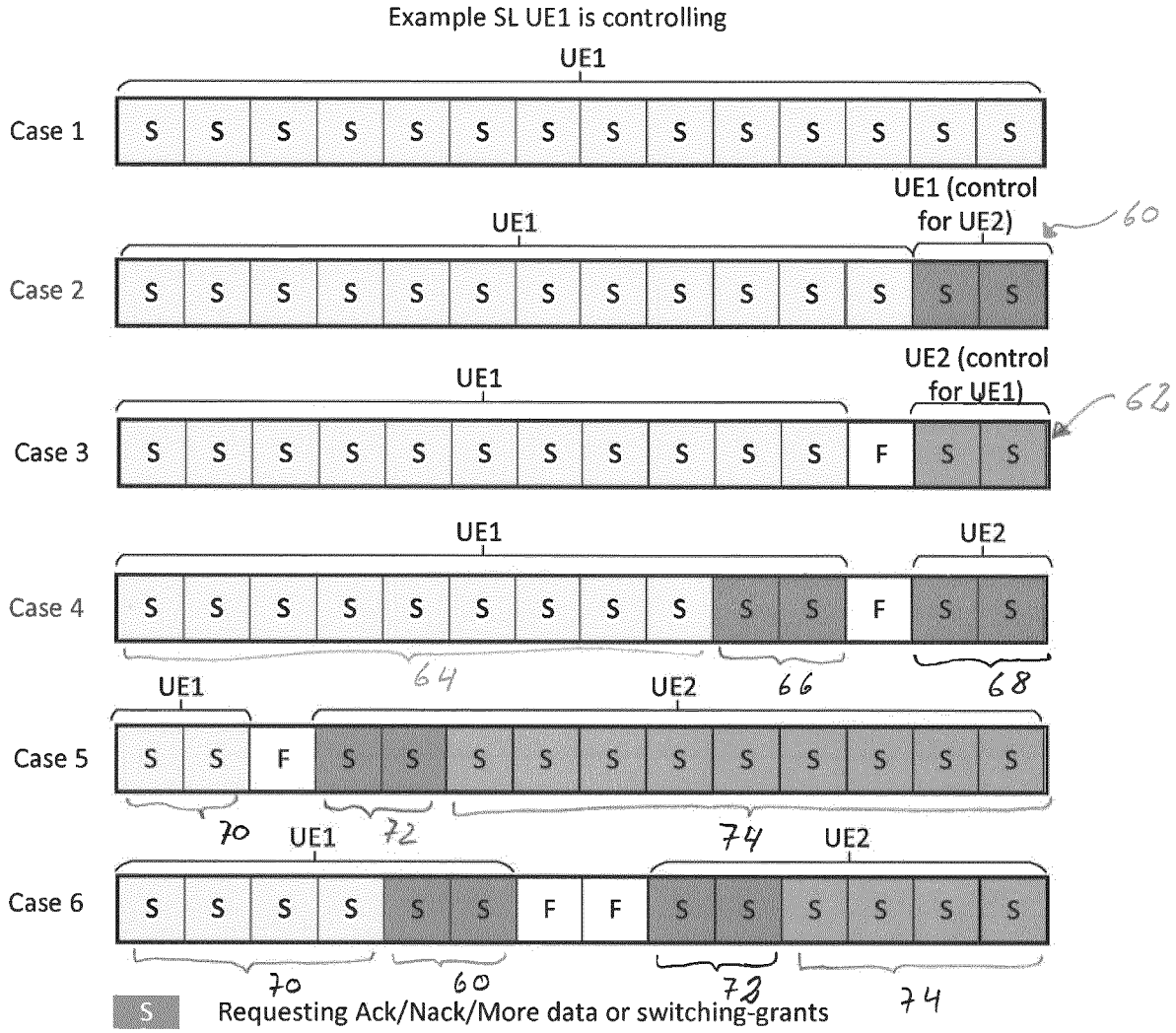
Example SL UE1 is controlling
UE1
Case 1
S S S S S S S S S S S S S S
UE1 (control for UE2)
60
UE1
Case 2
S S S S S S S S S S S S S
UE2 (control for UE1)
62
UE1
Case 3
S S S S S S S S S S S F S S
UE1
UE2
Case 4
S S S S S S S S S S S F S S
64
66
68
UE1
UE2
Case 5
S S F S S S S S S S S S S S
70
72
74
UE1
UE2
Case 6
S S S S S S F F S S S S S S
70
60
72
74
S
Requesting Ack/Nack/More data or switching-grants

Fig. 17

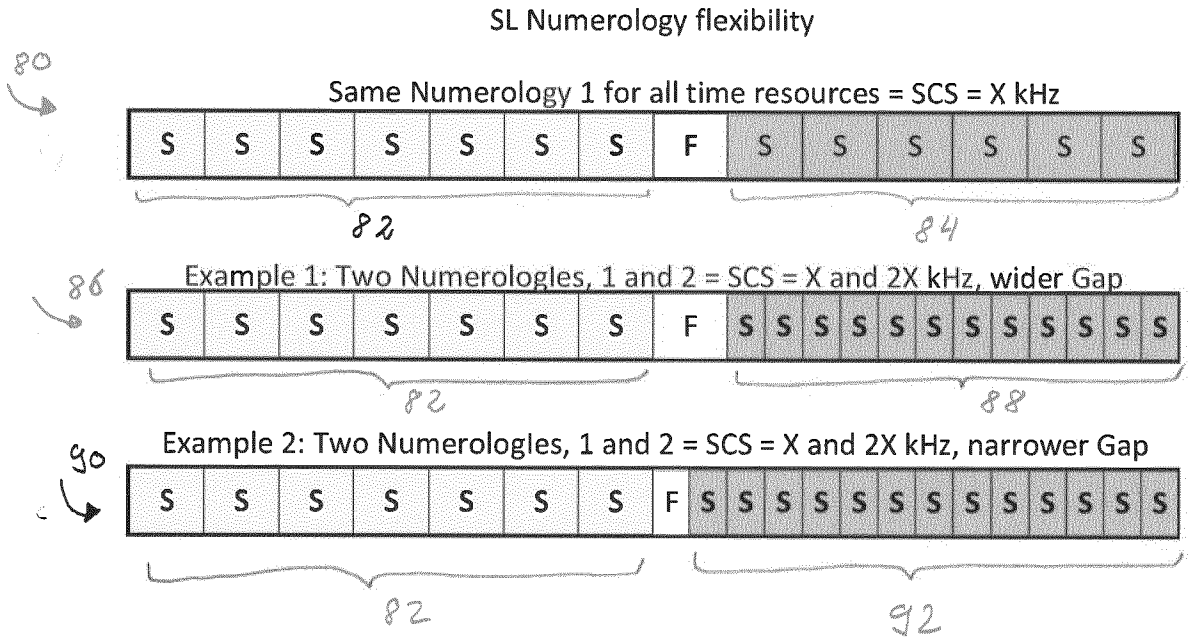
SL Numerology flexibility
80
Same Numerology 1 for all time resources = SCS = X kHz
S S S S S S S F S S S S S S
82
84
86
Example 1: Two Numerologies, 1 and 2 = SCS = X and 2X kHz, wider Gap
S S S S S S S F S S S S S S S S S S S S
82
88
90
Example 2: Two Numerologies, 1 and 2 = SCS = X and 2X kHz, narrower Gap
S S S S S S S F S S S S S S S S S S S S
82
92

Fig. 18

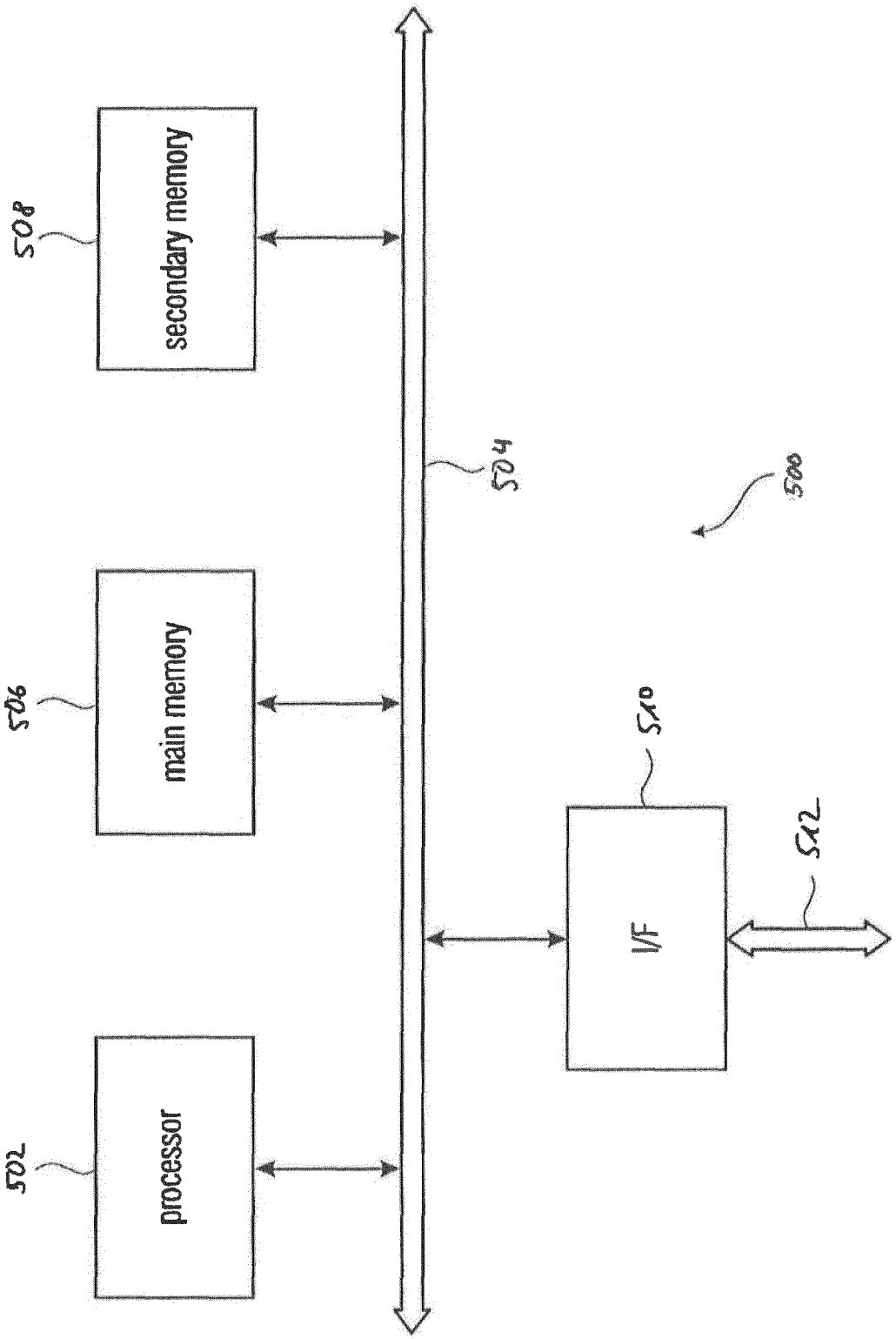
secondary memory
508
504
500
main memory
506
510
I/F
512
processor
502

Fig. 19

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/070123

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04L5/14
ADD.

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	HUAWEI ET AL: "Sidelink physical layer structure and procedure for NR V2X", 3GPP DRAFT; R1-1808093 , vol. RAN WG1, no. Gothenburg, Sweden; 20180820 - 20180824 10 August 2018 (2018-08-10), XP051515495, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94/Docs/R1%2D1808093%2Ezip [retrieved on 2018-08-10] Sections 1-4 ----- -/--	1-46

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

[X] See patent family annex.

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2019	28/10/2019

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	Dhibi, Youssef

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FUJITSU: "Considerations on sidelink physical layer structures", 3GPP DRAFT; R1-1808295 , vol. RAN WG1, no. Gothenburg, Sweden; 20180820 - 20180824 10 August 2018 (2018-08-10), XP051515679, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg%5Fran/WG1%5FRL1/TSGR1%5F94/Docs/R1%2D1808295%2Ezip [retrieved on 2018-08-10] Sections 1-3 -----	1-46
X	WO 2018/145019 A1 (INTEL IP CORP [US]) 9 August 2018 (2018-08-09) paragraph [0063] - paragraph [0075] paragraph [0119] - paragraph [0136] claims 1-5,14-19 -----	1-26, 29-46

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/070123

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2018145019 A1	09-08-2018	NONE	