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

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

(43) **International Publication Date**
27 February 2020 (27.02.2020)

WIPO | PCT

(10) **International Publication Number**
WO 2020/037536 A1

(51) **International Patent Classification:**
H04W 72/08 (2009.01)

(21) **International Application Number:**
PCT/CN2018/101702

(22) **International Filing Date:**
22 August 2018 (22.08.2018)

(25) **Filing Language:** English

(26) **Publication Language:** English

(71) **Applicants** *(for CN only)*: **NOKIA SHANGHAI BELL CO., LTD.** [CN/CN]; No. 388, Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN). **NOKIA SOLUTIONS AND NETWORKS OY** [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(71) **Applicant** *(for all designated States except CN)*: **NOKIA TECHNOLOGIES OY** [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(72) **Inventors: LI, Dong**; No. 388 Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN). **LIU, Yong**; No. 388 Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN). **WILDSCHEK, Torsten**; 8 Kimberland Way, Gloucester GL4 5TW (GB).

(74) **Agent: KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Centre, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,

(54) **Title:** METHOD, APPARATUS AND COMPUTER READABLE MEDIA FOR REFERENCE SIGNAL CONFIGURATION IN A WIRELESS COMMUNICATION SYSTEM

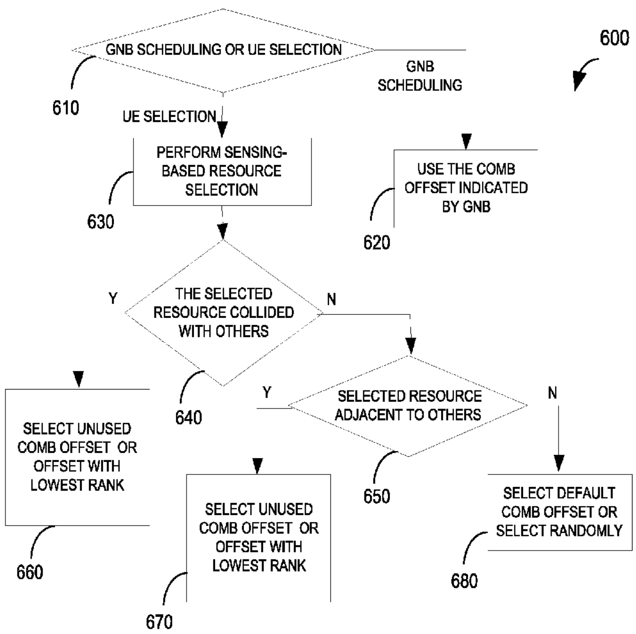

FIG. 6

(57) **Abstract:** Embodiments of the present disclosure relate to methods, apparatuses and computer program products for reference signal (RS) configuration in a wireless communication system. A method at a terminal device comprises determining a resource selection mode to be adopted for a transmission; in response to a first resource selection mode being determined, performing a channel sensing to select a resource for the transmission based on a result of channel sensing; determining a configuration for a RS of the transmission based on a traffic type of the transmission; and transmitting the RS in the selected resource based on the determined configuration. With some embodiments of the present disclosure, interference of RS may be reduced and communication performance can be improved.

WO 2020/037536 A1

[Continued on next page]

HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*

METHOD, APPARATUS AND COMPUTER READABLE MEDIA FOR REFERENCE SIGNAL CONFIGURATION IN A WIRELESS COMMUNICATION SYSTEM

FIELD

[0001] Non-limiting and example embodiments of the present disclosure generally relate to a technical field of wireless communication, and specifically to methods, apparatuses and computer program products for reference signal configuration in a wireless communication system.

BACKGROUND

[0002] This section introduces aspects that may facilitate better understanding of the disclosure. Accordingly, the statements of this section are to be read in this light and are not to be understood as admissions about what is in the prior art or what is not in the prior art.

[0003] In wireless systems, there is a requirement for supporting more and more terminal devices and increasing types of services. For instance, Vehicle to anything (V2X) sidelink (SL) was introduced in Long Term Evolution (LTE) Release 14 developed by the Third Generation Partnership Project (3GPP) to support direct communication of basic road safety services between vehicle and vehicle/pedestrian/infrastructure.

[0004] The increasing number of users and services brings a big challenge to the scarce frequency spectrum. To increase resource efficiency and/or system capacity, a plurality of transmissions may be allowed to occupy a same time-frequency resource, which in turn results in interference.

[0005] Solutions for reducing or mitigating interference caused by resource collision are desired.

SUMMARY

[0006] Various embodiments of the present disclosure mainly aim at providing methods, apparatuses and computer program products for reference signal configuration in a wireless communication system.

[0007] In a first aspect of the disclosure, there is provided a method implemented at a transmitter device. The method comprises determining a resource selection mode to be adopted for a transmission; in response to a first resource selection mode being determined, performing a channel sensing to select a resource for the transmission based on a result of channel sensing; determining a configuration for a RS of the transmission based on a traffic type of the transmission; and transmitting the RS in the selected resource based on the determined configuration.

[0008] In some embodiments, the method may further comprise: evaluating, based on the channel sensing, whether the transmission in the selected resource is to cause interference; and wherein the determining the configuration for the RS may comprise: determining the configuration for the RS of the transmission based on the traffic type and/or the evaluation.

[0009] In some embodiments, the evaluating may comprise evaluating at least one of the following: whether the selected resource collides with a further transmission of same traffic type; and whether there is a transmission of same traffic type occupying an adjacent resource of the selected resource. In some embodiments, the traffic type may comprise one of: a periodic traffic type and an aperiodic traffic type. In some embodiments, the evaluating may be performed in response to the traffic type being a periodic traffic type.

[0010] In some embodiments, the configuration for the RS may comprise one of: a frequency offset for a Comb resource structure of the RS, a time domain offset for a Comb resource structure of the RS, and an index for a RS configuration.

[0011] In some embodiments, determining the configuration for the RS of the transmission may comprise: in response to the selected resource being evaluated as colliding with a first number of further transmissions of the same traffic type, and the number of candidate configurations occupied by the first number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type of the transmission, selecting a candidate configuration unused by any of the first number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

[0012] In some embodiments, determining the configuration for the RS of the transmission may comprise: in response to the selected resource being evaluated as colliding with a first number of further transmissions of same traffic type, and the first number of further transmissions occupying all candidate configurations in the candidate configuration set, ranking candidate configurations used by the first number of further transmissions based on respective priority of the first number of further transmissions; and selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

[0013] In some embodiments, determining the configuration for the RS of the transmission may comprises: in response to the selected resource being evaluated to be free of collision with any further transmission of the same traffic type, selecting a default configuration as the configuration for the RS of the transmission, or selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

[0014] In some embodiments, determining the configuration for the RS of the transmission may comprise: in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and in response to a second number of further transmissions of the same traffic type being in the adjacent resource, and the number of candidate configurations occupied by the second number of further transmissions being smaller than the total number of candidate configurations of a candidate configuration set associated with the traffic type of the transmission, selecting a candidate configuration unused by any of the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

[0015] In some embodiments, the determining the configuration for the RS of the transmission may comprise: in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and in response to a second number of transmissions of the same traffic type being in the adjacent resource, and the second number of further transmissions occupying all candidate configurations in the candidate configuration set, ranking the candidate configurations used by the second number of further transmissions based on respective priority of the second number of further transmissions; and selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

[0016] In some embodiments, determining the configuration for the RS of the transmission may comprise: in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a transmission of the same traffic type in an adjacent resource of the selected resource; and in response to determining that no transmission of same traffic type being in the adjacent resource, selecting a default configuration as the configuration for the RS of the transmission, or selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

[0017] In some embodiments, determining the configuration for the RS of the transmission may comprise: determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource; in response to the number of candidate configurations occupied by the first number and the second number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type, selecting a candidate configuration unused by any of the first number and the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

[0018] In some embodiments, the determining the configuration for the RS of the transmission may comprise: determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource; in response to the first number and the second number of further transmissions occupying all candidate configurations in the candidate configuration set, ranking the candidate configurations occupied by the first number and the second number of further transmissions based on respective priority of the first number and the second number of further transmissions; and selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

[0019] In some embodiments, determining the configuration for the RS of the transmission may comprise: determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource; in response to a sum of the first number and the second number being zero, selecting a default configuration as the configuration for the RS of the transmission, or selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

[0020] In some embodiments, the priority of a further transmission is determined based on one or more of: whether the further transmission occupying a resource overlapping with the selected resource or occupying a resource adjacent to the selected resource; a size of a collided portion of the selected resource caused by the further transmission; a priority of a packet associated with the further transmission, a quality requirement of a packet associated with the further transmission, and a received signal strength of the further transmission.

[0021] In some embodiments, the determined configuration for the RS is valid for a plurality of transmissions including the transmission for a same packet. In another embodiment, the determined configuration for the RS is specific to the transmission.

[0022] In some embodiments, the determining the configuration for the RS of the transmission may further comprise: in response to the traffic type being an aperiodic traffic type, selecting a candidate configuration randomly from a candidate configuration set associated with the aperiodic traffic type as the configuration for the RS of the transmission.

[0023] In some embodiments, the method may further comprise: in response to a second resource selection mode being determined, receiving the configuration for the RS of the transmission from a network node. In some embodiments, the first resource selection mode may include an autonomous selection mode and the second resource selection mode may include a network node scheduling mode.

[0024] In some embodiments, the method may further comprise obtaining information of a first candidate configuration set associated with a first traffic type and a second candidate configuration set associated with a second traffic type from a network node. In some embodiments, one of the first candidate configuration set and the second candidate configuration set may be empty. In some embodiments, a union of the first candidate configuration set and the second candidate configuration set may include all available candidate configurations. In still another embodiment, the size of the union may be configured by a network node or predefined. Alternatively or in addition, in some embodiments, the size of the union may be specific to a resource pool configured/preconfigured for the transmission.

[0025] In some embodiment, the method may further comprise transmitting the determined configuration of the RS as a part of a control message associated with the selected resource.

[0026] In a second aspect of the disclosure, there is provided a method at a network device. The method comprises: configuring an autonomous resource selection mode for a transmission of a terminal device; and indicating, to the terminal device, a first set of reference signal candidate configurations associated with a first traffic type and a second set of reference signal candidate configurations associated with a second traffic type, for the terminal device to select from which a reference signal configuration for the transmission in response to the configured autonomous resource selection mode.

[0027] In a third aspect of the disclosure, there is provided an apparatus for reference signal configuration. The apparatus comprises: at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the apparatus at least to: determine a resource selection mode to be adopted for a transmission; in response to a first resource selection mode being determined, perform a channel sensing to select a resource for the transmission based on a result of channel sensing; determine a configuration for a RS of the transmission based on a traffic type of the transmission; and transmit the RS in the selected resource based on the determined configuration.

[0028] In a fourth aspect of the disclosure, there is provided an apparatus for communication. The apparatus comprises: at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the apparatus at least to: configure an autonomous resource selection mode for a transmission of a terminal device; and indicate, to the terminal device, a first set of reference signal candidate configurations associated with a first traffic type and a second set of reference signal candidate configurations associated with a second traffic type, for the terminal device to select from which a reference signal configuration for the transmission in response to the configured autonomous resource selection mode

[0029] In a fifth aspect of the present disclosure, there is provided an apparatus for reference signal configuration. The apparatus comprises means for determining a resource selection mode to be adopted for a transmission; means for performing a channel sensing to select a resource for the transmission based on a result of channel sensing in response to a first resource selection mode being determined; means for determining a configuration for a RS of the transmission based on a traffic type of the transmission; and means for transmitting the RS in the selected resource based on the determined configuration.

[0030] In a sixth aspect of the present disclosure, there is provided an apparatus for reference signal configuration. The apparatus comprises means for configuring an autonomous resource selection mode for a transmission of a terminal device; and means for indicating, to the terminal device, a first set of reference signal candidate configurations associated with a first traffic type and a second set of reference signal candidate configurations associated with a second traffic type, for the terminal device to select from which a reference signal configuration for the transmission in response to the configured autonomous resource selection mode.

[0031] In an seventh aspect of the disclosure, there is provided a computer program. The computer program comprises instructions which, when executed by an apparatus, causes the apparatus to carry out the method according to the first or second aspect of the present disclosure.

[0032] In an eighth aspect of the disclosure, there is provided a computer readable medium with a computer program stored thereon which, when executed by an apparatus, causes the apparatus to carry out the method of the first or second aspect of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The above and other aspects, features, and benefits of various embodiments of the present disclosure will become more fully apparent from the following detailed description with reference to the accompanying drawings, in which like reference signs are used to designate like or equivalent elements. The drawings are illustrated for facilitating better understanding of the embodiments of the disclosure and are not necessarily drawn to scale, in which:

[0034] FIG. 1 illustrates an example communication network in which embodiments of the present disclosure may be implemented;

[0035] FIGs. 2(a)-2(c) show resource selection scenarios with resource collision;

[0036] FIG. 3 shows a Cumulative Distribution Function (CDF) of cross correlation of different DMRS sequences;

[0037] FIG. 4 shows an example of Comb DMRS structure;

[0038] FIG. 5 shows a flowchart of a method for RS configuration according to an embodiment of the present disclosure;

[0039] FIG. 6 shows a flowchart of another method for RS configuration according to an embodiment of the present disclosure;

[0040] FIG. 7 shows a flowchart of still another method for RS configuration according to an embodiment of the present disclosure;

[0041] FIGs. 8-10 show examples Comb offset selection for a RS according to embodiments of the present disclosure;

[0042] FIG. 11 shows an example of determining RS configuration for a plurality of transmissions according to an embodiment of the present disclosure;

[0043] FIG. 12 shows a flowchart of a method at a network device for RS configuration according to an embodiment of the present disclosure; and

[0044] FIG. 13 shows a simplified block diagram of an apparatus that may be embodied as/in a network device or a terminal device.

DETAILED DESCRIPTION

[0045] Hereinafter, the principle and spirit of the present disclosure will be described with reference to illustrative embodiments. It should be understood that all these embodiments are given merely for one skilled in the art to better understand and further practice the present disclosure, but not for limiting the scope of the present disclosure. For example, features illustrated or described as part of one embodiment may be used with another embodiment to yield still a further embodiment. In the interest of clarity, not all features of an actual implementation are described in this specification.

[0046] References in the specification to "one embodiment," "an embodiment," "an example embodiment," and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0047] It shall be understood that although the terms "first" and "second" etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term "and/or" includes any and all combinations of one or more of the listed terms.

[0048] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be liming of example embodiments. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises", "comprising", "has", "having", "includes" and/or "including", when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0049] As used in this application, the term "circuitry" may refer to one or more or all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) combinations of hardware circuits and software, such as (as applicable):

(i) a combination of analog and/or digital hardware circuit(s) with software/firmware and

(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

(c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0050] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a computing device.

[0051] As used herein, the term "wireless communication system" refers to a system following any suitable wireless communication standards, such as New Radio (NR), Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), and so on. The "wireless communication system" may also be referred to as a "wireless communication network." Furthermore, communications between network devices, between a network device and a terminal device, or between terminal devices in the wireless communication network may be performed according to any suitable communication protocol, including, but not limited to, Global System for Mobile Communications (GSM), Universal Mobile Telecommunications System (UMTS), LTE, NR, wireless local area network (WLAN) standards, such as the IEEE 802.11 standards, and/or any other appropriate wireless communication standard either currently known or to be developed in the future.

[0052] As used herein, the term "network device" refers to a node in a wireless communication network via which a terminal device accesses the network and receives services therefrom. The network device may refer to a base station (BS) or an access point

(AP), for example, a node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a NR NB , a next generation NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth, depending on the applied terminology and technology.

[0053] The term "terminal device" refers to any end device capable of wireless communications. By way of example rather than limitation, a terminal device may also be referred to as a communication device, user equipment (UE), a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a smart phone, voice over IP (VoIP) phones, wireless local loop phones, a tablet, a wearable terminal device, a personal digital assistant (PDA), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, vehicle-mounted wireless terminal devices, wireless endpoints, mobile stations, laptop-embedded equipment (LEE), laptop-mounted equipment (LME), USB dongles, smart devices, wireless customer-premises equipment (CPE) and the like. In the following description, the terms "terminal device", "communication device", "terminal", "user equipment" and "UE" may be used interchangeably.

[0054] As yet another example, in an Internet of Things (IOT) scenario, a terminal device may represent a machine or other device that performs monitoring and/or measurements, and transmits the results of such monitoring and/or measurements to another terminal device and/or network equipment. The terminal device may in this case be a machine-to-machine (M2M) device, which may in a 3GPP context be referred to as a machine-type communication (MTC) device. As one particular example, the terminal device may be a UE implementing the 3GPP narrow band internet of things (NB-IoT) standard. Examples of such machines or devices are sensors, metering devices such as power meters, industrial machinery, or home or personal appliances, for example refrigerators, televisions, personal wearables such as watches etc. In other scenarios, a terminal device may represent a vehicle or other equipment that is capable of monitoring and/or reporting on its operational status or other functions associated with its operation. In some scenarios, the terminal device may include an end device involved in V2X communications.

[0055] As used herein, a DL transmission refers to a transmission from a network device to UE, an UL transmission refers to a transmission in an opposite direction, and a SL transmission refers to a transmission in V2X communications.

[0056] FIG. 1 illustrates an example wireless communication system 100 in which embodiments of the present disclosure may be implemented. As shown, the wireless communication system 100 may include one or more network devices, for example, network device 101. The network device 101 may be in a form of a BS, a NB, an eNB, a gNB, a virtual BS, a Base Transceiver Station (BTS), or a Base Station Subsystem (BSS), AP and the like.

[0057] In this example, network device 101 provides radio connectivity to a set of terminal devices 102, 103, and 104 within its coverage. It should be appreciated that in some embodiments, the network device may provide service to less or more terminal devices and the number of terminal devices shown in this example does not suggest any limitations as to the scope of the present disclosure.

[0058] A terminal device (e.g., terminal device 102) may access the wireless communication system via the network device 101, or communicate with another terminal device (e.g., terminal device 103 or 104) directly via D2D or V2X.

[0059] V2X SL was defined in LTE Release 14 to support direct communication of basic road safety services, including for example exchanging of vehicle status information such as position, speed and heading etc., between a vehicle and another vehicle or pedestrian/ infrastructure. In LTE Release 15, V2X SL was further enhanced with features of carrier aggregation, higher order modulation and latency reduction, to support more diversified services and more stringent service requirements.

[0060] Various modes for V2X are defined in 3GPP. In a first mode (also referred to as "mode 1"), a UE in a RRC_CONNECTED mode can request D2D resource from the network, and an eNB may grant a D2D resource to the UE via a physical layer signaling in a format of physical downlink control channel (PDCCH) downlink control indicator format 5 (DCI 5) or via a dedicated higher layer signalling. In a second mode (also referred to as "mode 2"), a UE is allowed to autonomously select a D2D resource for its transmission from a pool of available resources that is provided by the eNB via a broadcasted system information block (SIB) signalling or via a dedicated signaling. Unlike the first operation mode (mode-1), the second mode (mode-2) can be implemented also by UEs in a RRC_IDLE state. A third mode (also referred to as "mode 3") is similar to the mode 1, but also supports semi-persistent scheduling (SPS) of the sidelink besides a dynamic sidelink grant. In addition, a further UE autonomous resource selection mode (also referred to as "mode 4") is adopted in LTE V2X Release 14/15, in which sensing based resource (re)selection and reservation are applied, to avoid resource selection collisions as much as possible.

[0061] The sensing procedure for mode 4 is formulated based on assumptions of periodicity of V2X traffic (e.g. 100ms) and fixed transmission bandwidth occupancy (based on sub-channel number). In this way, vehicle UE tries to avoid using resources that have been reserved by other nearby vehicle UEs and thus reduce collision interference as much as possible. However, collision in resource selection may still exist in some cases.

[0062] For example, a threshold (e.g., a Physical Sidelink Shared Channel (PSSCH) Reference Signal Received Power (RSRP) threshold) may be used by a terminal device during sensing to decide whether a sensed resource reservation is to be precluded from a candidate resource set. The threshold depends on packet priorities of sensed UE (i.e., receiving (RX) priority) and the sensing UE (i.e., transmitting (TX) priority), and may be adjusted based on UE density relative to a size of a configured resource pool. Only sub-channels with a RSRP higher than the threshold may be precluded from the candidate resource set to reduce interference. A PSSCH-RSRP threshold may be scaled up to avoid precluding too many resources and guarantee a candidate resource set which is large enough (e.g. no less than 20% of the total resource size). However, if the threshold is set large, only a few sub-channels will be precluded from the candidate resource set, and in such a case, collision interference still exists in sub-channels with low RSRP. As another example, the sensing UE may not preclude a resource reserved by the sensed UE, if its TX priority is (much) higher than the RX priority of the sensed UE.

[0063] V2X will be further studied and enhanced in NR framework in 3GPP Release 16 to enable more service types and use cases with more stringent performance requirements as defined in TR 22.886 V16.0.0 and TS 22.186 V15.3.0. As discussed in the Study Item (SI) of NR V2X evaluation methodology, more V2X traffic types have to be supported by the NR V2X, which includes periodic V2X traffic with constant (or fixed pattern) of packet sizes, periodic V2X traffic with varying (even random) packet sizes and the aperiodic V2X traffic. Furthermore, in most cases, a V2X packet size (e.g. 2000 bytes and beyond) considered in NR V2X may be much larger than that (e.g. 190 bytes and 300 bytes) considered in conventional LTE V2X. The diversity in traffic types leads to more collision interference, and solutions for interference reduction have to be found to improve reliability of V2X communications. It should be appreciated that similar interference problem may exist in other non-V2X scenarios.

[0064] In current LTE V2X SL, a Zadoff-Chu sequence is used as a DMRS sequence for each DMRS symbol, where the DMRS sequence elements are transmitted over all subcarriers of a selected/scheduled frequency subband(s) (also referred to as sub-channel hereafter). If a selected resource for a transmission (partially or fully) collides with another transmission as shown in FIGs. 2(a)-(c), DMRS sequences of colliding UEs are generally non-orthogonal to each other. In particular, for a scenario with fully collided resource selection as shown in FIG. 2(a), even although DMRS sequences of colliding UEs may have the same length and align in subcarrier mapping position in a transmission time interval (TTI), the DMRS sequences are generally non-orthogonal to each other since it is highly possible that different UEs use different sequence root indexes. In a scenario with partially collided resource selection shown in FIGs. 2(b) or FIG. 2(c), it is apparent that collided DMRS sequences are non-orthogonal even if they have same sequence root index.

[0065] FIG. 3 shows a CDF of cross correlation of different DMRS sequences over a full sequence length and one physical resource block (PRB) length respectively. DMRS sequences with a same length of 144 and different root indexes and/or different cyclic shifts (CS) are used for generating the CDF. Due to channel frequency selectivity, the cross correlation DMRS sequences over a short length (called partial cross correlation here) of one PRB may result in a high correlation coefficient, and this may lead to degraded channel estimation performance in interference limited scenarios. As shown in FIG. 3, a partial correlation coefficient between DMRS sequences is quite high, which means that interference caused by collision (also referred to as collision interference) has a severe impact on channel estimation performance in this scenario.

[0066] Inventors of the present disclosure have realized that the interference problem may be handled at a transmitter side and/or a receiver side. Take NR V2X sidelink design as an example, one way for interference reduction is to adopt an enhanced reference signal (RS) design at the transmitter side, so as to make the RS (e.g., demodulation RS (DMRS)) orthogonal or quasi-orthogonal even if a selected resource collides with another transmission. Alternatively or in addition, advanced data detection mechanism may be utilized at the receiver side for interference rejection.

[0067] In some embodiments of the present disclosure, methods, apparatuses, and computer product (including computer readable media) are proposed for determining proper RS configuration so as to reduce interference. The RS may include, but is not limited to, DMRS.

[0068] In some embodiments, an adaptive Comb DMRS structure is proposed to provide better orthogonality in DMRS transmission, so as to combat potential collision interference. The proposed adaptive Comb DMRS structure may be applied to V2X communication, however, embodiments are not limited thereto, but could be applied more widely to any communication systems where similar problem exist.

[0069] In a Comb DMRS structure, a RS only occupies discontinuous (but equally spaced) frequency resources (e.g., subcarriers) and/or time resources (e.g., symbols) in a selected resource in a Comb-like manner. In a Comb DMRS structure with discontinuous frequency resources, a frequency offset may be used to indicate a starting frequency/subcarrier for the RS relative to a starting frequency of the selected resource, and a Comb size is used to indicate the total number of frequency offsets available for the Comb DMRS structure. FIG. 4 shows an example of Comb DMRS structure. DMRS may be time divisional multiplexed with data. As shown in FIG. 4, DMRS may be transmitted in DMRS symbols 411-414, while data may be transmitted in data symbols (e.g., symbol 421) in same transmission time interval (TTI). In addition, a symbol 422 may be reserved as guard symbol. In this example, the first Comb DMRS 401 (e.g., from terminal device 102 in FIG. 1) has a Comb offset of 0, and therefore occupies subcarriers 0, 2, 4, 6, 8 and 10 of the PRB with 12 subcarriers in total. Likewise, the second Comb DM RS 402 (e.g., from terminal device 103 in FIG. 1) has a Comb offset of 1, and occupies subcarriers 1, 3, 5, 7, 9 and 11 of the PRB. In this example Comb structure, there are totally two frequency offsets (i.e., 0 and 1) available, and as a result, the Comb structure has a Comb size of 2. Likewise, in a Comb DMRS structure with discontinuous time resources, a time domain offset may be used to indicate a starting OFDM symbol for the RS relative to a starting time point of the selected resource, and a Comb size is used to indicate the total number of time domain offsets available for the Comb DMRS structure. Both the frequency offset and the time domain offset may be referred to as a Comb offset for a DMRS Comb structure hereafter.

[0070] In some embodiments of the present disclosure, it is proposed that a RS configuration, e.g., a frequency offset for a Comb resource structure of the RS, a time domain offset for the Comb resource structure, a Comb size of the Comb structure, and/or an index for the RS configuration, may be determined adaptively, for example based on channel sensing, such that collision interference in RS may be reduced, even if the selected resource for data transmission collides with another transmission from other UE.

[0071] In some embodiments, the DMRS Comb size (e.g. 2 or 4) may be configured, for example in a resource pool specific manner. Alternatively, in some embodiments, the DMRS comb size (e.g., 2) may be predefined or fixed. As an example, the Comb size may be specified in a communication standard.

[0072] For illustration rather than limitation, the Comb DMRS structure (e.g., the Comb structure similar to that shown in FIG. 4) may be used in at least data channel in V2X sidelink. The Comb offset adaptively selected by a terminal device for RS of the data channel may be dynamically indicated by the terminal device in a corresponding control channel, for example via 1 bit for Comb size of 2. In some embodiments, the adaptively selected Comb offset may be broadcasted to other devices.

[0073] The Comb offset may be adaptively selected from a configured candidate offset set. In some embodiments, a communication system (e.g., the communication system 100 in FIG. 1) may support various types of traffic/services, and the configured candidate offset set may be associated with (or specific to) a particular traffic type. For instance, a network device may configure a first set of Comb offsets for a first traffic type (e.g., periodic traffic) and a second set of Comb offsets for a second traffic type (e.g., aperiodic traffic). In some embodiments, a union of the first set and the second set may include all available Comb offsets. However, it should be appreciated that embodiments are not limited thereto, and the network device may further configure a third set for a third traffic type in some embodiments and reserve some Comb offsets for the third set.

[0074] For example without limitation, a first set of Comb offset associated with a first type of V2X traffic may be configured for a DMRS of a physical data channel. The first type of V2X traffic may include one or more V2X services, for example periodic V2X service with fixed and/or varied payload sizes.

[0075] The allocated first set of Comb offsets (which may also be referred to as set one) may include one or more candidate Comb offsets. For transmitting a packet of the first type of V2X traffic (e.g., periodic traffic), a terminal device is only allowed to select a candidate Comb offset for a RS from the first set.

[0076] Likewise, a second set of Comb offset associated with a second type of V2X traffic may be configured for a DMRS of a physical data channel. The second type of V2X traffic may include one or more V2X services, for example an aperiodic V2X service.

[0077] The allocated second set of Comb offsets (which may also be referred to as set two) may include zero, one or more Comb offsets for the RS. For instance, the second set with zero Comb offset may indicate that the second type of V2X traffic is not supported in current resource pool. For transmitting a packet of the second type of V2X traffic (e.g., aperiodic traffic), a terminal device is only allowed to select a candidate Comb offset for the RS from the second set if it is not empty.

[0078] In some embodiments, a packet (e.g., a sildelink packet) may be transferred via a plurality of (re)transmissions, and in such a scenario, a single/common Comb offset may be selected for the plurality of (re)transmissions of the packet. Alternatively, in another embodiment, a terminal device may select a Comb offset separately for each of the plurality of (re)transmissions. The selected Comb offset may be indicated to one or more receivers via a V2X control channel.

[0079] Depending on a resource selection mode configured for a transmission, the Comb offset for a RS of a terminal device may be configured by a network node (e.g., an eNB or gNB, in gNB scheduling mode) or adaptively selected by the terminal device based on a result of channel sensing (e.g., in UE autonomous resource selection mode) from a set of candidate Comb offsets corresponding to a traffic type of the terminal device.

[0080] For instance, a V2X terminal device may be configured with a UE autonomous resource selection mode, and it may adaptively select a Comb offset for a RS to be transmitted in a given subband, such that the selected Comb offset is different from that used by other sidelink transmissions on (partially) collided subband(s). Alternatively or in addition, in some embodiments, the selected Comb offset may be different from that used by other sidelink transmission on one or more adjacent subbands of the given subband. Such an embodiment may be applied to avoid/reduce potential interference caused by possible resource extension of other sildelink transmission(s) in the adjacent subbands due to time varying payload size.

[0081] In some embodiments, the number of Comb offsets occupied by the colliding and/or adjacent sidelink transmissions may be equal to the Comb size, which may imply that all candidate Comb offsets have been occupied by the colliding and/or adjacent sidelink transmissions. In such a case, a terminal device may select a Comb offset based on ranking of Comb offsets used by the colliding and/or adjacent sidelink transmissions. For example, the terminal device may reuse a Comb offset with the lowest rank for its RS. As an example rather than limitation, the ranking of Comb offsets used by the colliding and/or adjacent sidelink transmissions may be performed according to one or more of the following factors: whether the transmission is a colliding or adjacent transmission, a packet priority of a colliding/adjacent transmission, a size of a collided portion of the subband (also referreed to as collision size hereafter), and a received signal strength (e.g. PSSCH-RSRP) of the transmission.

[0082] To facilitate a better understanding of solutions proposed in the present disclosure, some further example embodiments will be described below with reference to FIGs 5-12.

[0083] FIG. 5 shows a flow chart of an example method 500 according to an embodiment of the present disclosure. The method may be performed by a terminal device, for example, the terminal device 102, 103 or 104 in FIG. 1. Just for illustration purpose, the method 500 will be described below with reference to the terminal device 102 and the communication system 100 illustrated in FIG. 1; however, it should be appreciated that embodiments of the present disclosure are not limited thereto.

[0084] At block 510, the terminal device 102 determines a resource selection mode to be adopted for a transmission. In some embodiments, the resource selection mode may be a network scheduling mode where a resource for the transmission of the terminal device 102 is scheduled by a network node (e.g., the network node 101 in FIG. 1), or a UE autonomous resource selection mode where the terminal device 102 selects a resource for the transmission autonomously. In some embodiments, the communication system 100 may support more resource selection modes (e.g., mode 1 to mode 4 defined in 3GPP for V2X), and accordingly the terminal device 102 may determine the resource selection mode from more candidates modes at block 510.

[0085] In some embodiments, at block 510, the terminal device 102 may determine the resource selection mode based on a configuration signaling from the network device 101. Alternatively or in addition, the terminal device 102 may determine the resource selection mode implicitly based on one or more of: a service/traffic type, and a property or requirement of an operating frequency band.

[0086] At block 515, the terminal device checks whether the resource selection mode is a first resource selection mode or a second transmission mode. As an example, the first resource selection mode may include an UE autonomous resource selection mode, and the second resource selection mode may include a network scheduling mode.

[0087] At block 520, in response to a first resource selection mode (e.g., a UE autonomous resource selection mode) being determined, the terminal device 102 performs channel sensing and selects a resource for the transmission based on a result of the channel sensing.

[0088] The channel sensing may be performed by the terminal device 102 by detecting received signal strength (e.g., RSRP) of a resource (e.g., a subband or a sub-channel). Alternatively or in addition, in some embodiments, the terminal device 102 may perform the channel sensing by detecting a control channel in a resource and obtaining information related to resource selection from the control channel.

[0089] Embodiments are not limited to any specific algorithm for selecting the resource for the transmission based on the channel sensing, for example a result of channel sensing obtained in a previous transmission period. Just for example, the terminal device 102 may select a resource with lowest RSRP for the transmission. Or, the terminal device 102 may take a priority of a detected transmission into consideration during the selection of the resource.

[0090] At block 540, the terminal device 102 determines a configuration for a RS of the transmission at least based on the traffic type of the transmission.

[0091] For example, if the traffic type associated with the transmission of the terminal device 102 is an aperiodic traffic, the terminal device 102 may select a candidate configuration (e.g., a candidate Comb offset) randomly from a candidate configuration set (e.g., a set of candidate Comb offsets) associated with the aperiodic traffic type.

[0092] At block 550, terminal device 102 transmits the RS in the selected resource based on the determined configuration for the RS.

[0093] The RS may be, but is not limited to, a DMRS. In some embodiments, the configuration for the RS may include a frequency offset (or Comb offset) for a Comb resource structure of the RS, a time domain offset for a Comb resource structure of the RS, or, an index for a RS configuration. However, it should be appreciated that embodiments of the present disclosure are not limited to such configuration of the RS; instead, the configuration of the RS may be any proper parameter of the RS which may be adaptively adjusted to achieve orthorgonality with other RS transmissions.

[0094] Method 500 enables determining a RS configuration for a transmission adaptively at least based on a traffic type of the transmission, and may reduce/avoid interference in RS.

[0095] In some embodiments, method 500 may further comprise a block 530, where the terminal device 102 evaluates whether the transmission in the selected resource may cause interference based on the channel sensing. For example, the terminal device 102 may evaluate whether the transmission in the selected resource will collide with a further transmission of same traffic type (e.g., periodic traffic). Alternatively or in addition, the terminal device 102 may evaluate whether a transmission of the same traffic type will occupy an adjacent resource of the selected resource. If time varying payload size is supported by the traffic type, the transmission in the adjacent resource may increase its resource occupation in a later time interval and cause collision with the transmission in the selected resource. In such a case, the evaluating of whether a transmission of the same traffic type will occupy an adjacent resource of the selected resource is beneficial. Then at block 540, the terminal device 102 may determine the configuration for the RS of the transmission based on both the traffic type and/or the evaluation.

[0096] Though embodiments are not limited to any specific way for determining the RS configuration adaptively based on the evaluation and/or the traffic type in the first resource selection mode, some example embodiments will be provided below for illustration purpose.

[0097] In some example embodiments, a result of the evaluation performed by the terminal device at block 530 of FIG. 5 may indicate that the selected resource will be free of collision with any further transmission of the same traffic type (e.g., periodic traffic). In response to the evaluation result, the terminal device 102 may select a default configuration (e.g., a default Comb offset) as the configuration for the RS of the transmission, or, select a configuration (e.g., a Comb offset) randomly from a candidate configuration set (e.g., a set of candidate Comb offsets) associated with the traffic type (e.g., periodic traffic) of the transmission as the configuration for the RS of the transmission.

[0098] In some embodiments, a result of the evaluation performed by the terminal device at block 530 of FIG. 5 may indicate that the selected resource may collide with a first number of further transmissions of same traffic type (e.g., periodic traffic), and the number of candidate configurations occupied by the first number (e.g., 1) of further transmissions is smaller than the total number (e.g., 2 or 4) of candidate configurations in a candidate configuration set associated with the traffic type of the transmission, which means that there is at least one free candidate configuration in the candidate configuration set not used by the first number of further transmissions. In response to the evaluation result, the terminal device 102 may selects a free candidate configuration for the RS from the candidate configuration set, to make the RS of the transmission orthogonal in frequency to RSs of the first number of further transmissions. As an example without limitation, the terminal device 102 may select a frequency offset (or a Comb offset) from a set of candidate Comb offsets associated with the traffic type, and the selected first frequency offset is different from a frequency offset for a RS of any of the first number of further transmissions. Or in other words, a frequency offset unused by RS of any of the first number of further transmissions is selected.

[0099] As another example, a result of the evaluation performed at block 530 may indicate that the selected resource may collide with a first number of further transmissions of same traffic type, and the first number (e.g., 2) of further transmissions will occupy all candidate configurations (e.g., candidate Comb Offsets) in the candidate configuration set. It means no free candidate configuration is available in the candidate configuration set. In response to the evaluation result, at block 540, the terminal device 102 may rank the candidate configurations occupied by the first number of further transmissions based on respective priority of the further transmissions; and select a candidate configuration (e.g., a Comb offset) the lowest rank from the candidate configuration set as the configuration for the RS of the transmission.

[00100] The priority of a further transmission in the first number of further transmissions used for the ranking may be determined based on, for example but not limited to, one or more of the following factors: whether the further transmission occupying a resource colliding with the selected resource or adjacent to the selected resource, a size of a collided portion of the selected resource caused by the further transmission, a priority of a packet associated with the further transmission, a quality requirement of a packet associated with the further transmission, and a received signal strength of the further transmission.

[00101] As an example, the terminal device 102 may be configured with a set of DMRS comb offsets with a size of two (i.e. Comb Offset=0 or 1 are included in the set), and the evaluating at block 530 of FIG. 5 shows that the selected resource may collide with two further transmissions. Assume that a first transmission of the two further transmissions uses a Comb offset of 0 for its RS, and a second transmission of the two further transmissions uses a Comb offset of 1 for its RS. If 60% of the selected resource collides with the first transmission, and only 20% of the selected resource collides with the second transmission, the terminal device 102 may assign a high rank to Comb offset 0 used by the first transmission and a low rank to Comb offset 1 used by the second transmission. Then accordingly, at block 540, the terminal device 102 may select a Comb offset of 1 for its RS of the transmission from the set.

[00102] As shown in FIG. 5, in some embodiments, method 500 may optionally comprise a block 560 where the terminal device 102 transmits the determined configuration of the RS as a part of a control message associated with the selected resource. The transmission of the RS and the transmission of the configuration of the RS may be time divisional multiplexed in some embodiments. Alternatively or in addition, the configuration of the RS may be transmitted in a broadcast manner.

[00103] In some example embodiments, the method 500 may further comprise a block 570 as shown in FIG. 5, where the terminal device 102 may receive the configuration for the RS of the transmission from the network device 101. This block may be performed by the terminal device 102 if a second resource selection mode is determined at block 510. For instance, the first resource selection mode may include an autonomous resource selection mode, while the second resource selection mode may include a gNB scheduling mode. That is, in some embodiments, adaptive RS configuration may be performed in an autonomous resource selection mode, while scheduling based RS configuration may be performed in a gNB scheduling mode by the terminal device 102.

[00104] In some embodiments, when determining the RS configuration adaptively for its transmission at block 540 of FIG. 5, the terminal device 102 may consider both colliding transmissions (i.e., transmissions occupying a resource which at least partly overlaps with the selected resource) and adjacent transmissions (i.e., transmissions occupying an adjacent resource of the selected resource) indicated by the evaluating result.

[00105] In addition, the colliding transmissions and the adjacent transmissions may be treated separately when determining the RS configuration (e.g., Comb offset for the RS). FIG. 6 shows an example method 600 for RS configuration with such a mechanism. Method 600 may be considered as a specific example implementation of method 500. In particular, blocks 640-680 may be considered as an example implementation of block 540 of FIG. 5.

[00106] In this example, at block 610, the terminal device 102 determines a resource selection mode for its transmission, e.g., whether a gNB scheduling mode or UE autonomous selection mode is configured by the network. If a gNB scheduling mode is configured, at block 620, the terminal device 102 uses a DMRS comb offset as indicated by a gNB scheduling signaling, and the Comb DMRS selection for current transmission is over. Otherwise, e.g., when a UE autonomous selection mode is configured, the terminal device 102 performs a sensing-based resource selection at block 630 to select a resource (e.g., a subband) for its sidelink transmission.

[00107] At block 640, the terminal device 102 evaluates, based on sensing results, whether there exist (fully or partially) colliding sidelink transmissions in the selected resource. If colliding sidelink transmission exists, the terminal device selects a Comb offset for the RS by performing block 660. At block 660, the terminal device 102 determines whether the number of Comb offsets occupied by the colliding sidelink transmissions with the same traffic type (e.g. periodic traffic type or aperiodic traffic type) is smaller than the total number of Comb offsets in a configured set of Comb offsets associated with the traffic type. If so, the terminal device 102 selects one DMRS comb offset that is different from that used by RSs of the colliding sidelink transmissions. Otherwise, the terminal device 102 may determine that no free Comb offset is available in the set of Comb offset candidate, and rank the Comb offsets used by the colliding sidelink transmissions according to one or more of at least the following factors: packet priority of the colliding transmissions, a size of collided resource portion caused by the collision transmissions, and a PSSCH-RSRP. Then based on the ranking, the terminal device 102 may determine to use a DMRS comb offset with the lowest rank for RS of its transmission. The Comb offset selected in this way may avoid interference to high priority transmissions, and/or, reduce the interference to the minimum level.

[00108] If colliding sidelink transmission does not exist, the terminal device 102 may further determine whether there is a transmission of same traffic type in an adjacent resource of the selected resource at block 650. If there is no transmission of same traffic type in the adjacent resource, the terminal device 102 may select a default configuration (e.g., a default Comb offset) for the RS of the transmission, or select a configuration (e.g., a Comb offset) randomly from the candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission, as shown in block 680 of FIG.8.

[00109] If there are one or more transmissions (also referred to as adjacent transmissions) of the same traffic type (e.g., periodic traffic) in the adjacent resource, the terminal device 102 selects the configuration (e.g., a Comb offset) for the RS at block 670. As an example, at block 670, if the number of candidate configurations used by the adjacent transmissions with the same traffic type is smaller than the size (e.g., 2 or 4) of the set of candidate configurations associated with the traffic type, the terminal device 102 selects, from the candidate configuration set, a candidate configuration unused by any of the adjacent transmissions as the configuration for the RS of its transmission. For example, the terminal device 102 may select a DMRS comb offset that is different from those used for RS of the adjacent transmissions. If the number of candidate configurations occupied by the adjacent transmissions is equal to the size (e.g., 2 or 4) of the set of candidate configurations associated with the traffic type, which means that all candidate configurations in the set are already used by the adjacent transmissions, the terminal device 102 may rank the candidate configurations (e.g., Comb offsets) occupied by the adjacent sidelink transmissions, for example based on priorities of the adjacent sidelink transmissions. The priority of an adjacent transmission may be determined according to one or more of at least the following factors: packet priority of the adjacent transmission, and PSSCH-RSRP. Then the terminal device 102 may use the DMRS comb offset with the lowest rank as a Comb offset for its RS in the selected resource.

[00110] FIG. 7 shows another alternative method 700 for RS configuration, where the colliding transmissions and the adjacent transmissions are treated jointly when determining the RS configuration (e.g., Comb offset for the RS). Blocks 730-750 may be considered as an example implementation of block 540 of FIG. 5.

[00111] In this example, if the terminal device 102 determines at block 710 that a gNB scheduling mode is configured, it uses a DMRS Comb offset as indicated by a gNB scheduling signaling at block 760, and the comb DMRS selection for current transmission is over. Otherwise, e.g., when the terminal device 102 determines at block 710 that a UE autonomous selection mode is configured, the terminal device 102 performs sensing-based resource selection at block 720 to select a resource for its sidelink transmission. In addition, based on the channel sensing result, at block 730, terminal device 102 determines existence and the number of colliding transmissions and the number of adjacent transmissions of the same traffic type for the selected resource. If no colliding or adjacent transmissions exist, at block 740, terminal device 102 select a default DMRS comb offset (if it is predefined or configured) from a Comb offset set associated with the traffic type. Or, the terminal device 102 may randomly select one DMRS Comb offset from the Comb offset set.

[00112] If (fully or partially) colliding transmissions and/or adjacent transmissions exist, the terminal device 102 determines configuration for the RS (e.g., Comb offset) at block 750. For example, if the number of Comb offsets used by the colliding and the adjacent transmissions with the same traffic type (e.g. periodic traffic type, or aperiodic traffic type) as terminal device 102 is smaller than the size of the Comb offset set associated the traffic type, terminal device 102 selects one DMRS Comb offset that is different from those used by the colliding and adjacent transmissions. On the other hand, if the number of Comb offsets used by the colliding and adjacent transmissions is equal to the size of the Comb offset set, which means that no free candidate Comb offset is available in the Comb offset set, terminal device 102 may rank Comb offsets used by the colliding and adjacent transmissions, for example according to priorities of the colliding and adjacent transmissions which may be determined by one or more of the following factors: whether the transmission is a colliding transmission or an adjacent transmission, a size of a collided resource portion caused by a colliding transmission, a packet priority of a colliding or adjacent transmission, a quality requirement of a packet associated with a colliding or adjacent transmission, and a received signal strength (e.g., PSSCH-RSRP) of the colliding or adjacent transmission.

[00113] FIGs. 8-11 show more examples for adaptively selecting a Comb offset for a RS by considering adjacent transmissions. Though these examples will be described below still

with reference to terminal device 102 in FIG. 1, it should be appreciated that same mechanism may be implemented by any terminal device.

[00114] In the example shown in FIG. 8, it is assumed that a first DMRS Comb offset set S1 for a first traffic type has a size of 2 (e.g., S1={0,1}), and only one adjacent sidelink transmission for the selected resource 801 of terminal device 102 is detected. In this example, Comb offset=1 is used by the adjacent sidelink transmission in resource 802, and terminal device 102 chooses Comb Offset=0 for its RS to avoid collision with the adjacent transmission.

[00115] The avoidance of Comb offset collision with the adjacent sidelink transmission is motivated by a fact that resource 802 occupied by the adjacent sidelink transmission is known from its reservation information obtained in a previous transmission period, but a V2X packet size of the adjacent transmission in current transmission period may be increased largely compared with that in the previous transmission period, which means that the occupied resource 802 may be extended to adjacent subband(s), e.g., resource 801. Therefore, it is possible that the transmission by the terminal device 102 in the selected resource 801 may partially collide with the adjacent transmission in current transmission period. Then in such a case, selecting a Comb offset different from that of the adjacent transmission is beneficial.

[00116] Note that terminal device 102 may obtain further information about priority and/or RSRP of the adjacent transmission via channel sensing, and take such information into consideration when selecting a Comb offset. In the example shown in FIG. 9, it is assumed that the terminal device 102 selected a resource 901, and two adjacent sidelink transmissions in resources 902 and 903 are detected via channel sending in a previous transmission period. The two adjacent sidelink transmissions use Comb offsets 0 and 1 respectively, as shown in FIG. 9. If the terminal device 102 is allocated a Comb offset set S1={0,1}, then there is no free Comb offset for selection in this example. In this case, the Comb offsets used by the two adjacent sidelink transmissions may be ranked, for example according to priorities of the two adjacent sidelink transmissions. The priority may be determined based on one or more of at least the following factors: packet priority (e.g., Prio1 and Prio2 for the two adjacent transmissions respectively), and received signal strength (e.g., PSSCH-RSRP, in this example, RSRP1 and RSRP2 for the two adjacent transmissions respectively). Terminal device 102 selects a Comb offset with the lowest rank. For example, if the first adjacent transmission in resource 902 has a lower priority compared with the second adjacent transmission in resource 903, the Comb offset 1 used by the first adjacent transmission is assigned a lower rank than

Comb offset 0, and the terminal device 102 may use the Comb Offset 1 for its RS in the selected resource 901. On the other hand, if the terminal device 102 is allocated a larger Comb offset set, e.g., a set S={0,1,2,3}, it may randomly select an unused DMRS Comb offset from the set S.

[00117] In the example shown in FIG. 10, the terminal device 102 selected a resource 1001 for its transmission, and besides two adjacent sidelink transmissions in adjacent resources 1002 and 1003, a colliding transmission in resource 1001 is detected, for example based on sensing in a previous transmission period. The sensing result may indicate Comb offset, Priority (also referred to as Prio), and RSRP for each detected transmission. For example, (Comb offset 1, Prio 1, RSRP 1) for a transmission from UE 1, (Comb offset 0, Prio 2, RSRP 2) for a transmission from UE 2, and (Comb offset 1, Prio 3, RSRP 3) for a transmission from UE 3. In this case, the terminal device 102 may select a DMRS Comb offset adaptively, for example, by using method 500, 600 or 700 described with reference to FIGs. 5-7. For example, the terminal device 102 may select a DMRS comb offset different from that used by the collided sidelink transmission. That is, if the colliding transmission uses a Comb offset of 1, and the Comb offset set configured for the traffic type of terminal device 102 is S1={0,1}, the terminal device 102 may choose a Comb offset of 0.

[00118] Alternatively, considering that all Comb offsets are used by the colliding and adjacent transmissions, i.e., no free Comb offset is available, the terminal device 102 may firstly rank the Comb offsets used by the colliding transmission and the two adjacent transmissions, and then select a Comb offset with the lowest rank. The ranking may be based on priority of the colliding and adjacent transmissions, and the priority may be determined based on one or more of at least the following factors: collision or adjacent transmission, packet priority, collision size (i.e., a size of a collided resource) caused by a colliding or adjacent transmission, and received signal strength (e.g. PSSCH-RSRP). For instance, the colliding transmission in resource 1001 may be assigned a higher priority than the adjacent transmissions in resources 1002 and 1003, and accordingly, the Comb offset 1 used by the colliding transmission has a higher rank. In this example, the terminal device 102 determines to use a Comb offset 0.

[00119] In some embodiments, terminal device 102 may perform a plurality of (re)transmissions for a same packet (e.g., V2X packet), in order to increase coverage or improve performance. In this case, there may be different options for selecting RS configurations (e.g., DMRS comb offsets) for the plurality of (re)transmissions. As an option, the terminal device 102 may determine a single RS configuration (e.g., DMRS comb offset) for the multiple (re)transmissions. For example, a Comb offset selected according to a method described above with references to FIGs. 5-10 is valid for a plurality of (re)transmission. As another alternative, the terminal device 102 may determine a Comb offset for each (re)transmission separately, as shown in FIG. 11.

[00120] In the example of FIG. 11, terminal device 102 has two (re)transmissions for a same packet, and different resources 1101 and 1102 are selected for the two (re)transmissions 1110 and 1120. Then terminal device 102 selects a Comb offset for RS of each (re)transmission independently, for example using any method described with reference to FIGs. 5-10. For example, a Comb offset 1 may be selected for the first (re)transmission 1110 in resource 1001, so as to avoid interference with an adjacent transmission in resource 1103, and a Comb offset 0 may be selected for the second (re)transmission 1120 in resource 1102, so as to avoid interference with an adjacent transmission in resource 1104. The selected Comb offsets may be indicated by a control channel associated with corresponding (re)transmissions. This alternative provides more flexibility for RS configuration selection and potentially better performance, at a cost of increased signalling overhead in the control channel.

[00121] In some embodiments, the terminal device 102 may determine the configuration for the RS adaptively based on the evaluation of whether interference will be caused (e.g., whether there is potential colliding and/or adjacent transmissions) only when the traffic type associated with the transmission is a periodic traffic type. In other words, if the traffic type associated with the transmission of the terminal device 102 is an aperiodic traffic, the terminal device 102 may not perform the evaluation operation (e.g., at block 530 in FIG. 5, or block 640 in FIG. 6 or block 730 in FIG. 7), and may not take the result of the evaluation into consideration when determining a configuration for a RS of the transmission. Instead, the terminal device may just select a candidate configuration (e.g., a candidate Comb offset) randomly from a candidate configuration set (e.g., a set of candidate Comb offsets) associated with the aperiodic traffic type.

[00122] For example, the communication system 100 in FIG. 1 may support at least two types of traffic for V2X, among which the first V2X traffic type includes only periodic traffic with fixed or varied payload sizes and is assigned a first Comb offset set S1={0,1}, and the second V2X traffic type includes only aperiodic traffic and is assigned a second Comb offset set S2={2, 3}. The terminal device 102 may obtain information of the first Comb offset set associated with a first traffic type and the second Comb offset set associated with the second traffic type from the network node 101, for example, via a signaling. If the terminal device

102 has traffic of the second type (i.e., aperiodic traffic) to transmit, it may randomly select a DMRS Comb offset from the associated Comb offset set S2={2,3}. The reason of random selection of DMRS comb offset is that there is generally no resource reservation for an aperiodic packet transmission in next transmission period, and as a result, the terminal device 102 with the second traffic type cannot know whether there will be colliding and/or adjacent transmission of same traffic type.

[00123] In some embodiments, the second Comb offset set S2 may be configured as empty to indicate that the second traffic type is not supported. In some embodiments, the terminal device 102 may obtain information on the total number (e.g., 4) of available Comb offsets (i.e., a size of the Comb structure) and the first Comb offset set S1 (e.g., {0,1}). In such embodiments, the terminal device 102 may derive the second Comb offset set S2 implicitly by assuming that the second Comb offset set S2 includes Comb offsets that are not included in the first Comb Offset set S1.

[00124] The total number of available Comb offsets (i.e., a size of the Comb structure) may be configured by the network device, or predefined. Alternatively or in addition, the size of the Comb structure may be specific to a configured/preconfigured resource pool for the transmission.

[00125] As another example, a first V2X traffic type includes only periodic traffic with fixed or varied payload sizes and is allocated a Comb offset set S1={0}, while a second V2X traffic type includes only aperiodic traffic and is allocated a Comb offset set S2={1}. Then a union of these two Comb offset sets forms a set S={0, 1} which includes all available Comb offsets. In this example, the total number of Comb offsets (i.e., the size of the Comb structure) is 2, which may be configured, or predefined. Furthermore, in this example, since there is only one candidate comb offset in each Comb offset set (S1 or S2) associated with a traffic type, a configuration for a RS is determined implicitly by corresponding traffic type, and adaptive selection based on evaluation or channel sensing is unnecessary anymore.

[00126] FIG. 12 shows a flow chart of another example method 1200 according to an embodiment of the present disclosure. The method 1200 may be performed by a network device, for example, network device 101 in FIG. 1. Just for illustration purpose, the method 1200 will be described below with reference to the network device 101 and the communication system 100 illustrated in FIG. 1; however, it should be appreciated that embodiments of the present disclosure are not limited thereto.

[00127] As shown in FIG. 12, at block 1210, network device 101 configures an autonomous resource selection mode for a transmission of a terminal device, for example terminal device 102, 103 or 104 in FIG. 1. At block 1220, the network device 101 indicates to the terminal device, a first set of reference signal candidate configurations associated with a first traffic type and a second set of reference signal candidate configurations associated with a second traffic type, for the terminal device to select from which a RS configuration for the transmission in response to the configured autonomous resource selection mode.

[00128] The information transmitted by the network device 101 enables a terminal device to determine its RS configuration adaptively, so as to reduce interference in RS.

[00129] As described with reference to FIGs. 5-11, the RS configuration may include a Comb offset for the RS. In some embodiments, the first traffic type may include periodic traffic type and the second traffic type may include aperiodic traffic type.

[00130] Some embodiments of the present disclosure provide an apparatus for RS configuration. The apparatus may be implemented in/as a terminal device, for example, terminal device 102, 103 or 104 in FIG. 1. The apparatus includes means for determining a resource selection mode to be adopted for a transmission; means for performing a channel sensing to select a resource for the transmission based on a result of channel sensing in response to a first resource selection mode being determined; means for determining a configuration for a RS of the transmission based on a traffic type of the transmission; and means for transmitting the RS in the selected resource based on the determined configuration. In some embodiments, the apparatus may further comprise means for evaluating, based on the channel sensing, whether the transmission in the selected resource is to cause interference, and the means for means for determining the configuration for the RS may be configured to determine the configuration for the RS based on the evaluation and/or the traffic type of the transmission.

[00131] In some embodiments, the apparatus may be configured to implement method 500, 600 or 700 and relevant details related to RS configuration described with reference to FIGs. 5-11 also apply here.

[00132] Some embodiments of the present disclosure provide another apparatus which may be implemented in/as a network device, for example network device 101 in FIG. 1. The apparatus includes means for configuring an autonomous resource selection mode for a transmission of a terminal device; and means for indicating, to the terminal device, a first set of reference signal candidate configurations associated with a first traffic type and a second set of reference signal candidate configurations associated with a second traffic type, for the terminal device to select from which a reference signal configuration for the transmission in response to the configured autonomous resource selection mode.

[00133] In some embodiments, the apparatus may be configured to implement method 1200, and therefore relevant details provided with reference to method 1200 also apply here.

[00134] FIG. 13 illustrates a simplified block diagram of a further apparatus 1300 that may be embodied in/as a network device (e.g., the network device 101 in FIG. 1) or a terminal device (e.g., UE 102, 103 or 104 in FIG. 1). The apparatus may be used for RS configuration in a wireless communication system.

[00135] As shown by the example of FIG. 13, apparatus 1300 comprises a processor 1310 which controls operations and functions of apparatus 1300. For example, in some embodiments, the processor 1310 may implement various operations by means of instructions 1330 stored in a memory 1320 coupled thereto. The memory 1320 may be any suitable type adapted to local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory terminal devices, magnetic memory terminal devices and systems, optical memory terminal devices and systems, fixed memory and removable memory, as non-limiting examples. Though only one memory unit is shown in FIG. 13, a plurality of physically different memory units may exist in apparatus 900.

[00136] The processor 1310 may be any proper type adapted to local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors DSPs and processors based on multicore processor architecture, as non-limiting examples. The apparatus 1300 may also comprise a plurality of processors 1310.

[00137] The processors 1310 may also be coupled with a transceiver 1340 which enables reception and transmission of information. For example, the processor 1310 and the memory 1320 can operate in cooperation to implement any of the methods 500, 600, 700, or 1200 described with reference to FIGs. 5-12. It shall be appreciated that all the features described above with reference to FIGs. 5-12 also apply to apparatus 1300, and therefore will not be detailed here.

[00138] Various embodiments of the present disclosure may be implemented by a computer program or a computer program product executable by one or more of the processors (for example processor 1310 in FIG. 13), software, firmware, hardware or in a combination thereof.

[00139] Although some of the above description is made in the context of a communication network shown in FIG. 1, it should not be construed as limiting the spirit and scope of the present disclosure. The principle and concept of the present disclosure may be more generally applicable to other scenarios.

[00140] In addition, the present disclosure may also provide a carrier containing the computer program as mentioned above (e.g., computer instructions/program 1330 in FIG.13). The carrier includes a computer readable storage medium. The computer readable storage medium may include, for example, an optical compact disk or an electronic memory device like a RAM (random access memory), a ROM (read only memory), Flash memory, magnetic tape, CD-ROM, DVD, Blue-ray disc and the like. The computer readable storage medium has a computer program/instructions stored thereon which, when executed by at least one processor (e.g., processor 1310 in FIG. 13) of a device, causes the device to carry out a method, for example method 5, 600, 700 or 1200.

[00141] The carrier may include a transmission medium. The transmission medium may include, for example, electrical, optical, radio, acoustical or other form of propagated signals, such as carrier waves, infrared signals, and the like.

[00142] The techniques described herein may be implemented by various means so that an apparatus implementing one or more functions of a corresponding apparatus described with an embodiment comprises not only prior art means, but also means for implementing the one or more functions of the corresponding apparatus and it may comprise separate means for each separate function, or means that may be configured to perform two or more functions. For example, these techniques may be implemented in hardware (e.g., circuit or a processor), firmware, software, or combinations thereof. For a firmware or software, implementation may be made through modules (e.g., procedures, functions, and so on) that perform the functions described herein.

[00143] Some example embodiments herein have been described above with reference to block diagrams and flowchart illustrations of methods and apparatuses. It will be appreciated that each block of the block diagrams and flowchart illustrations, and combinations of blocks in the block diagrams and flowchart illustrations, respectively, may be implemented by various means including computer program product or computer program instructions. These computer program instructions may be loaded onto a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions which execute on the computer or other programmable data processing apparatus create means for implementing the functions specified in the flowchart block or blocks.

[00144] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any implementation or of what may be claimed, but rather as descriptions of features that may be specific to particular embodiments of particular implementations. Certain features that are described in this specification in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[00145] It will be obvious to a person skilled in the art that, as the technology advances, the inventive concept may be implemented in various ways. The above described embodiments are given for describing rather than limiting the disclosure, and it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the disclosure as those skilled in the art readily understand. Such modifications and variations are considered to be within the scope of the disclosure and the appended claims. The protection scope of the disclosure is defined by the accompanying claims.

WHAT IS CLAIMED IS:

1. An apparatus for wireless communication, comprising:

at least one processor; and

at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the apparatus at least to:

determine a resource selection mode to be adopted for a transmission;

in response to a first resource selection mode being determined, perform a channel sensing to select a resource for the transmission based on a result of channel sensing;

determine a configuration for a reference signal, RS, of the transmission based on a traffic type of the transmission; and

transmit the RS in the selected resource based on the determined configuration.

2. The apparatus of Claim 1, wherein the apparatus is further caused to:

evaluate, based on the channel sensing, whether the transmission in the selected resource is to cause interference; and

wherein the apparatus is caused to determine the configuration for the RS of the transmission based on a traffic type of the transmission as follows:

determine the configuration for the RS of the transmission based on the traffic type and the evaluation.

3. The apparatus of Claim 2, wherein the apparatus is caused to evaluate whether the transmission in the selected resource is to cause interference as follows:

evaluate at least one of:

whether the selected resource collides with a further transmission of same traffic type; and

whether there is a transmission of same traffic type occupying an adjacent resource of the selected resource.

4. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated as colliding with a first number of further transmissions of the same traffic type, and the number of candidate configurations occupied by the first number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type of the transmission, select a candidate configuration unused by any of the first number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

5. The apparatus of Claim 2, the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated as colliding with a first number of further transmissions of same traffic type, and the first number of further transmissions occupying all candidate configurations in the candidate configuration set,

rank candidate configurations used by the first number of further transmissions based on respective priority of the first number of further transmissions; and

select, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

6. The apparatus of Claim 2, the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated to be free of collision with any further transmission of the same traffic type,

select a default configuration as the configuration for the RS of the transmission, or

select a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

7. The apparatus of Claim 2, the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated to be free of collision with any further transmission, determine whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and

in response to a second number of further transmissions of the same traffic type being in the adjacent resource, and the number of candidate configurations occupied by the second number of further transmissions being smaller than the total number of candidate configurations of a candidate configuration set associated with the traffic type of the transmission, select a candidate configuration unused by any of the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

8. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated to be free of collision with any further transmission, determine whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and

in response to a second number of transmissions of the same traffic type being in the adjacent resource, and the second number of further transmissions occupying all candidate configurations in the candidate configuration set,

rank the candidate configurations used by the second number of further transmissions based on respective priority of the second number of further transmissions; and

select, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

9. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the selected resource being evaluated to be free of collision with any further transmission, determine whether there is a transmission of the same traffic type in an adjacent resource of the selected resource; and

in response to determining that no transmission of same traffic type being in the adjacent resource,

select a default configuration as the configuration for the RS of the transmission, or

select a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

10. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

determine a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to the number of candidate configurations occupied by the first number and the second number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type, select a candidate configuration unused by any of the first number and the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

11. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

determine a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to the first number and the second number of further transmissions occupying all candidate configurations in the candidate configuration set,

rank the candidate configurations occupied by the first number and the second number of further transmissions based on respective priority of the first number and the second number of further transmissions; and

select, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

12. The apparatus of Claim 2, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

determine a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to a sum of the first number and the second number being zero,

select a default configuration as the configuration for the RS of the transmission, or

select a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

13. The apparatus of any of Claims 5, 8 and 11, wherein the priority of a further transmission is determined based on one or more of:

whether the further transmission occupying a resource overlapping with the selected resource or occupying a resource adjacent to the selected resource;

a size of a collided portion of the selected resource caused by the further transmission;

a priority of a packet associated with the further transmission,

a quality requirement of a packet associated with the further transmission, and

a received signal strength of the further transmission.

14. The apparatus of Claim 2, wherein the apparatus is caused to evaluate whether the transmission in the selected resource is to cause interference in response to the traffic type being a periodic traffic type.

15. The apparatus of Claim 1, wherein the determined configuration for the RS is valid for a plurality of transmissions including the transmission for a same packet.

16. The apparatus of Claim 1, wherein the determined configuration for the RS is specific to the transmission.

17. The apparatus of Claim 1, wherein the traffic type comprises one of: a periodic traffic type and an aperiodic traffic type.

18. The apparatus of Claim 1, wherein the configuration for the RS comprises one of:

a frequency offset for a Comb resource structure of the RS,

a time domain offset for a Comb resource structure of the RS, and

an index for a RS configuration.

19. The apparatus of Claim 1, wherein the apparatus is caused to determine the configuration for the RS of the transmission as follows:

in response to the traffic type being an aperiodic traffic type, select a candidate configuration randomly from a candidate configuration set associated with the aperiodic traffic type as the configuration for the RS of the transmission.

20. The apparatus of Claim 1, the apparatus is further caused to:

in response to a second resource selection mode being determined, receive the configuration for the RS of the transmission from a network node.

21. The apparatus of Claim 20, wherein the first resource selection mode includes an autonomous selection mode and the second resource selection mode includes a network node scheduling mode.

22. The apparatus of Claim 1, the apparatus is further caused to:

obtain information of a first candidate configuration set associated with a first traffic type and a second candidate configuration set associated with a second traffic type from a network node.

23. The apparatus of Claim 22, wherein one of the first candidate configuration set and the second candidate configuration set is empty.

24. The apparatus of Claim 22, wherein a union of the first candidate configuration set and the second candidate configuration set includes all available candidate configurations.

25. The apparatus of Claim 24, wherein a size of the union is configured by a network node or predefined.

26. The apparatus of Claim 24, wherein a size of the union is specific to a resource pool configured or preconfigured for the transmission.

27. The apparatus of Claim 1, the apparatus is further caused to:

transmit the determined configuration of the RS as a part of a control message associated with the selected resource.

28. An apparatus for wireless communication, comprising:

at least one processor; and

at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the apparatus at least to:

configure an autonomous resource selection mode for a transmission of a terminal device; and

indicate, to the terminal device, a first set of reference signal, RS, candidate configurations associated with a first traffic type and a second set of RS candidate configurations associated with a second traffic type, for the terminal device to select from which a RS configuration for the transmission in response to the configured autonomous resource selection mode.

29. The apparatus of Claim 28, wherein the first traffic type includes periodic traffic type and the second traffic type includes aperiodic traffic type.

30. The apparatus of Claim 28, wherein a RS candidate configuration includes a candidate for one of:

a frequency offset for a Comb resource structure of the RS,

a time domain offset for a Comb resource structure of the RS, and

an index for a RS configuration.

31. A method for wireless communication, comprising:

determining a resource selection mode to be adopted for a transmission;

in response to a first resource selection mode being determined, performing a channel sensing to select a resource for the transmission based on a result of channel sensing;

determining a configuration for a reference signal, RS, of the transmission based on a traffic type of the transmission; and

transmitting the RS in the selected resource based on the determined configuration.

32. The method of Claim 31, further comprising:

evaluating, based on the channel sensing, whether the transmission in the selected resource is to cause interference; and

wherein determining a configuration for the RS of the transmission comprises:

determining the configuration for the RS of the transmission based on the traffic type and the evaluation.

33. The method of Claim 32, wherein the evaluating comprises evaluating at least one of the following:

whether the selected resource collides with a further transmission of same traffic type; and

whether there is a transmission of same traffic type occupying an adjacent resource of the selected resource.

34. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

in response to the selected resource being evaluated as colliding with a first number of further transmissions of the same traffic type, and the number of candidate configurations occupied by the first number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type of the transmission, selecting a candidate configuration unused by any of the first number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

35. The method of Claim 32, wherein determining a configuration for the RS of the transmission based on the evaluation and a traffic type of the transmission comprises:

in response to the selected resource being evaluated as colliding with a first number of further transmissions of same traffic type, and the first number of further transmissions occupying all candidate configurations in the candidate configuration set,

ranking candidate configurations used by the first number of further transmissions based on respective priority of the first number of further transmissions; and

selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

36. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

in response to the selected resource being evaluated to be free of collision with any further transmission of the same traffic type,

selecting a default configuration as the configuration for the RS of the transmission, or

selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

37. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and

in response to a second number of further transmissions of the same traffic type being in the adjacent resource, and the number of candidate configurations occupied by the second number of further transmissions being smaller than the total number of candidate configurations of a candidate configuration set associated with the traffic type of the transmission, selecting a candidate configuration unused by any of the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

38. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a further transmission of the same traffic type in an adjacent resource of the selected resource; and

in response to a second number of transmissions of the same traffic type being in the adjacent resource, and the second number of further transmissions occupying all candidate configurations in the candidate configuration set,

ranking the candidate configurations used by the second number of further transmissions based on respective priority of the second number of further transmissions; and

selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

39. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

in response to the selected resource being evaluated to be free of collision with any further transmission, determining whether there is a transmission of the same traffic type in an adjacent resource of the selected resource; and in response to determining that no transmission of same traffic type being in the adjacent resource,

selecting a default configuration as the configuration for the RS of the transmission,

or

selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

40. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to the number of candidate configurations occupied by the first number and the second number of further transmissions being smaller than the total number of candidate configurations in a candidate configuration set associated with the traffic type, selecting a candidate configuration unused by any of the first number and the second number of further transmissions from the candidate configuration set as the configuration for the RS of the transmission.

41. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to the first number and the second number of further transmissions occupying all candidate configurations in the candidate configuration set,

ranking the candidate configurations occupied by the first number and the second number of further transmissions based on respective priority of the first number and the second number of further transmissions; and

selecting, from the candidate configuration set, a candidate configuration with the lowest rank as the configuration for the RS of the transmission.

42. The method of Claim 32, wherein determining the configuration for the RS of the transmission comprises:

determining a first number of further transmissions of the same traffic type colliding with the transmission in the selected resource, and a second number of further transmissions of the same traffic type occupying an adjacent resource of the selected resource;

in response to a sum of the first number and the second number being zero,

selecting a default configuration as the configuration for the RS of the transmission,

or

selecting a candidate configuration randomly from a candidate configuration set associated with the traffic type of the transmission as the configuration for the RS of the transmission.

43. The method of any of Claims 35, 38 and 41, wherein the priority of a further transmission is determined based on one or more of:

whether the further transmission occupying a resource overlapping with the selected resource or occupying a resource adjacent to the selected resource;

a size of a collided portion of the selected resource caused by the further transmission;

a priority of a packet associated with the further transmission,

a quality requirement of a packet associated with the further transmission, and

a received signal strength of the further transmission.

44. The method of Claim 31, wherein determining the configuration for the RS of the transmission further comprises:

in response to the traffic type being an aperiodic traffic type, selecting a candidate configuration randomly from a candidate configuration set associated with the aperiodic traffic type as the configuration for the RS of the transmission.

45. The method of Claim 31, wherein the determined configuration for the RS is valid for a plurality of transmissions including the transmission for a same packet.

46. The method of Claim 31, wherein the determined configuration for the RS is specific to the transmission.

47. The method of Claim 31, wherein the evaluating is performed in response to the traffic type being a periodic traffic type.

48. The method of Claim 31, wherein the traffic type comprises one of: a periodic traffic type and an aperiodic traffic type.

49. The method of Claim 31, wherein the configuration for the RS comprises one of:

a frequency offset for a Comb resource structure of the RS,

a time domain offset for a Comb resource structure of the RS, and

an index for a RS configuration.

50. The method of Claim 31, further comprising:

in response to a second resource selection mode being determined, receiving the configuration for the RS of the transmission from a network node.

51. The method of Claim 50, wherein the first resource selection mode includes an autonomous selection mode and the second resource selection mode includes a network node scheduling mode.

52. The method of Claim 31, further comprising:

obtaining information of a first candidate configuration set associated with a first traffic type and a second candidate configuration set associated with a second traffic type from a network node.

53. The method of Claim 31, wherein one of the first candidate configuration set and the second candidate configuration set is empty.

54. The method of Claim 52, wherein a union of the first candidate configuration set and the second candidate configuration set includes all available candidate configurations.

55. The method of Claim 54, wherein a size of the union is configured by a network node or predefined.

56. The method of Claim 54, wherein a size of the union is specific to a resource pool configured or preconfigured for the transmission.

57. The method of Claim 31, further comprising:

transmitting the determined configuration of the RS as a part of a control message associated with the selected resource.

58. A method for wireless communication, comprising:

configuring an autonomous resource selection mode for a transmission of a terminal device; and

indicating, to the terminal device, a first set of reference signal, RS, candidate configurations associated with a first traffic type and a second set of RS candidate configurations associated with a second traffic type, for the terminal device to select from which a RS configuration for the transmission in response to the configured autonomous resource selection mode.

59. The method of Claim 58, wherein the first traffic type includes periodic traffic type and the second traffic type includes aperiodic traffic type.

60. The method of Claim 58, wherein a RS candidate configuration includes a candidate for one of:

a frequency offset for a Comb resource structure of the RS,

a time domain offset for a Comb resource structure of the RS, and

an index for a RS configuration.

61. An apparatus for wireless communication, comprising:

means for determining a resource selection mode to be adopted for a transmission;

means for performing a channel sensing to select a resource for the transmission based on a result of channel sensing in response to a first resource selection mode being determined;

means for determining a configuration for a reference signal, RS, of the transmission based on a traffic type of the transmission; and

means for transmitting the RS in the selected resource based on the determined configuration.

62. An apparatus for wireless communication, comprising:

means for configuring an autonomous resource selection mode for a transmission of a terminal device; and

means for indicating, to the terminal device, a first set of reference signal, RS, candidate configurations associated with a first traffic type and a second set of RS candidate configurations associated with a second traffic type, for the terminal device to select from which a RS configuration for the transmission in response to the configured autonomous resource selection mode.

63. A computer readable medium with a computer program stored thereon which, when executed by at least one processor of a device, causes the device to carry out the method of any of claims 31-60.

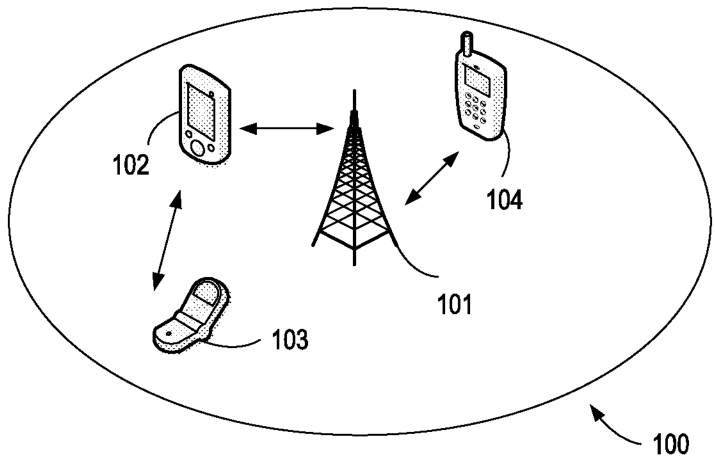
102
104
101
103
100

FIG. 1

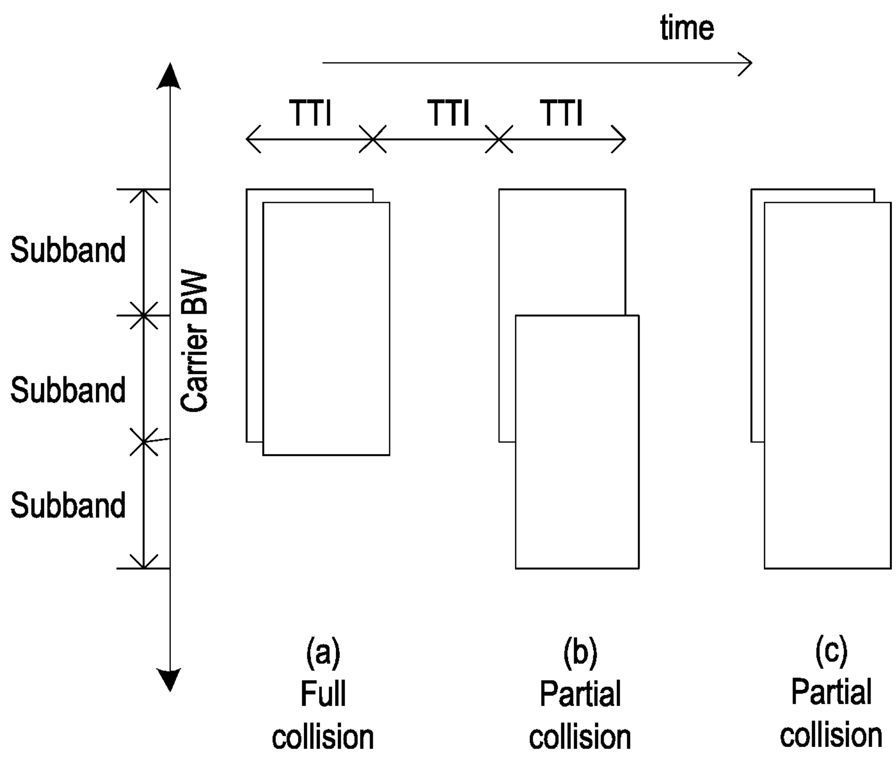
time
TTI
TTI
TTI
Subband
Subband
Subband
Carrier BW
(a)
Full
collision
(b)
Partial
collision
(c)
Partial
collision

FIG. 2

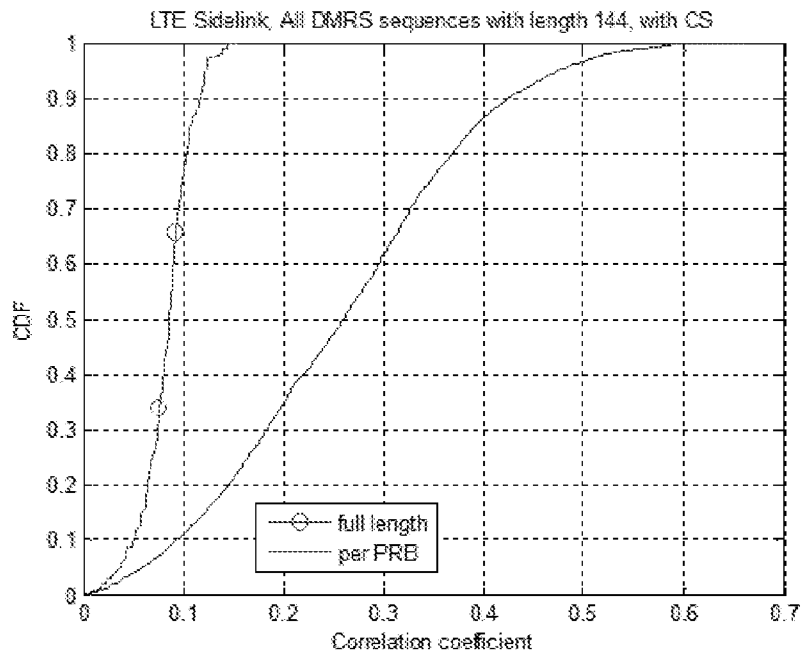
LTE Sidelink, All DMRS sequences with length 144, with CS
CDF
Correlation coefficient
full length
per PRB
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

FIG. 3

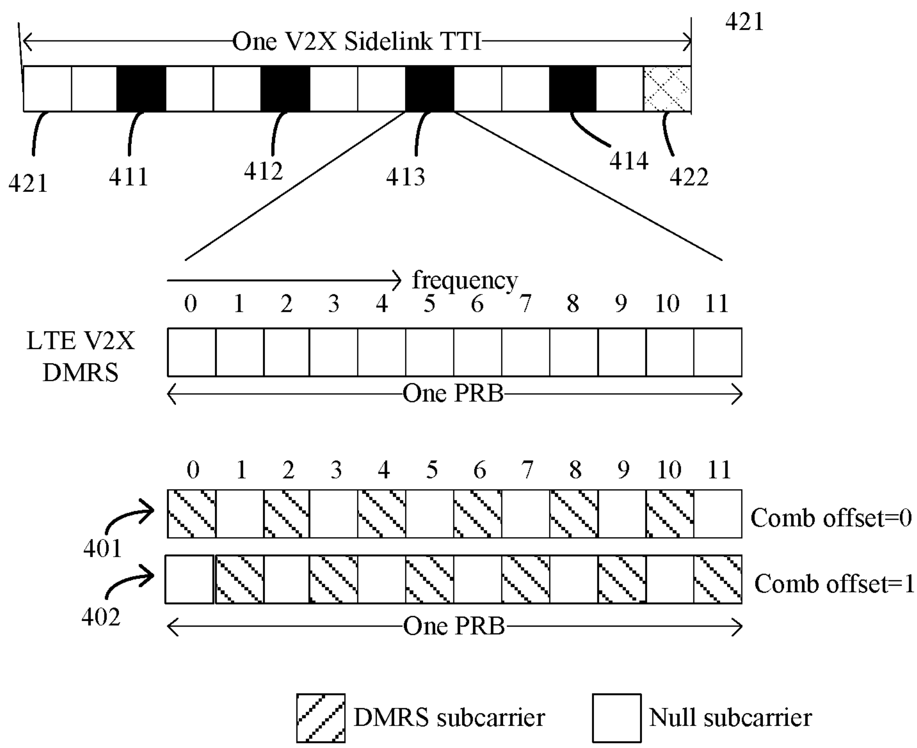
One V2X Sidelink TTI
421
421
411
412
413
414
422
frequency
0 1 2 3 4 5 6 7 8 9 10 11
LTE V2X DMRS
One PRB
0 1 2 3 4 5 6 7 8 9 10 11
401
402
Comb offset=0
Comb offset=1
One PRB
DMRS subcarrier
Null subcarrier

FIG. 4

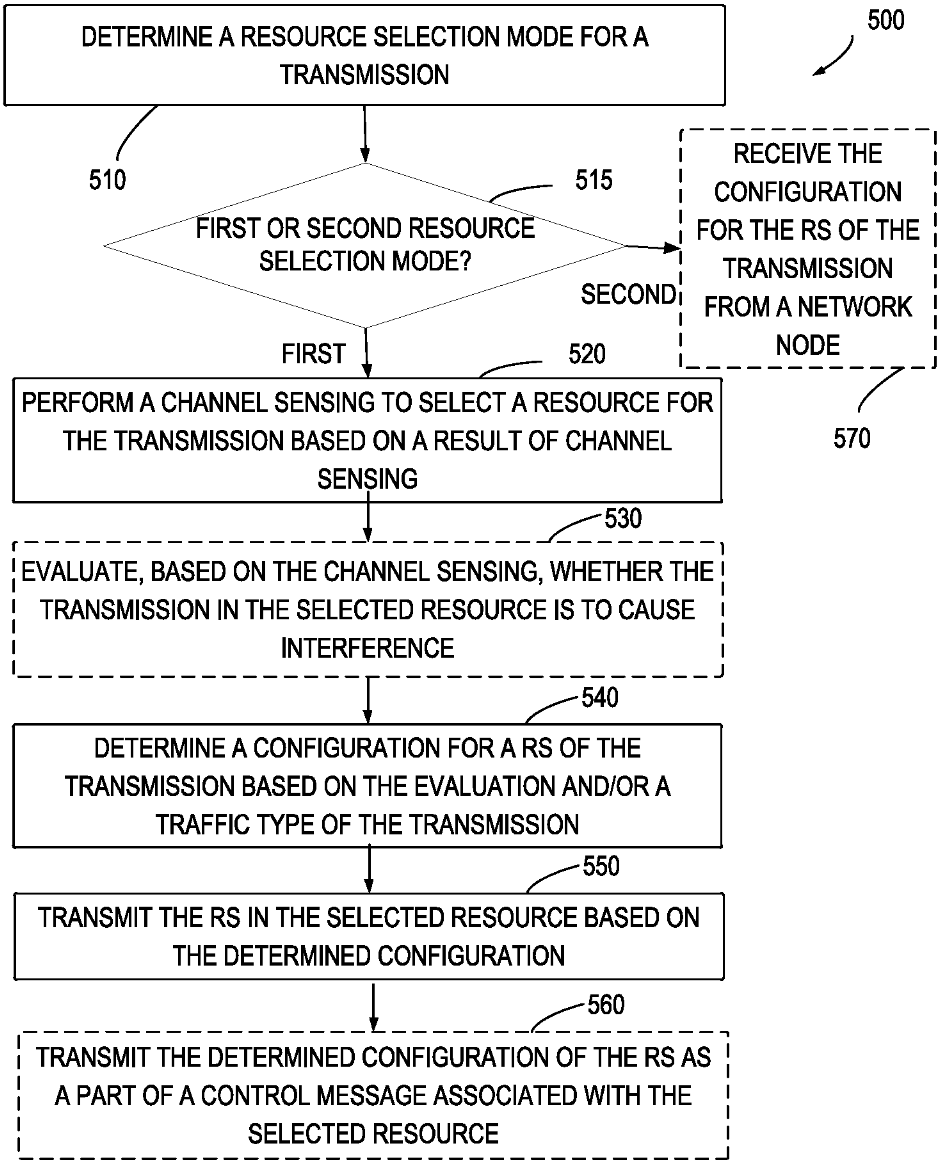
500
DETERMINE A RESOURCE SELECTION MODE FOR A TRANSMISSION
510
515
FIRST OR SECOND RESOURCE SELECTION MODE?
SECOND
RECEIVE THE CONFIGURATION FOR THE RS OF THE TRANSMISSION FROM A NETWORK NODE
570
FIRST
520
PERFORM A CHANNEL SENSING TO SELECT A RESOURCE FOR THE TRANSMISSION BASED ON A RESULT OF CHANNEL SENSING
530
EVALUATE, BASED ON THE CHANNEL SENSING, WHETHER THE TRANSMISSION IN THE SELECTED RESOURCE IS TO CAUSE INTERFERENCE
540
DETERMINE A CONFIGURATION FOR A RS OF THE TRANSMISSION BASED ON THE EVALUATION AND/OR A TRAFFIC TYPE OF THE TRANSMISSION
550
TRANSMIT THE RS IN THE SELECTED RESOURCE BASED ON THE DETERMINED CONFIGURATION
560
TRANSMIT THE DETERMINED CONFIGURATION OF THE RS AS A PART OF A CONTROL MESSAGE ASSOCIATED WITH THE SELECTED RESOURCE

FIG. 5

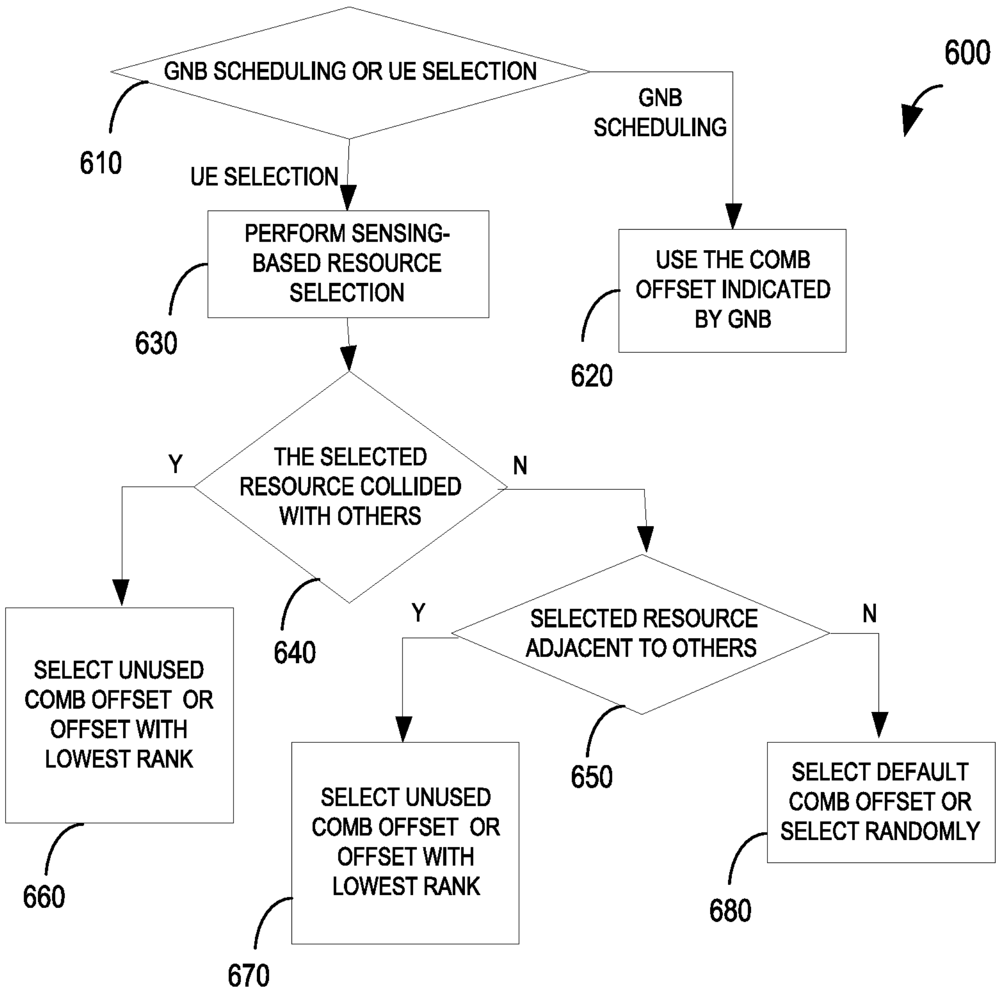
600
GNB SCHEDULING OR UE SELECTION
610
UE SELECTION
GNB SCHEDULING
PERFORM SENSING-BASED RESOURCE SELECTION
630
USE THE COMB OFFSET INDICATED BY GNB
620
THE SELECTED RESOURCE COLLIDED WITH OTHERS
Y
N
640
SELECTED RESOURCE ADJACENT TO OTHERS
Y
N
650
SELECT UNUSED COMB OFFSET OR OFFSET WITH LOWEST RANK
660
SELECT UNUSED COMB OFFSET OR OFFSET WITH LOWEST RANK
670
SELECT DEFAULT COMB OFFSET OR SELECT RANDOMLY
680

FIG. 6

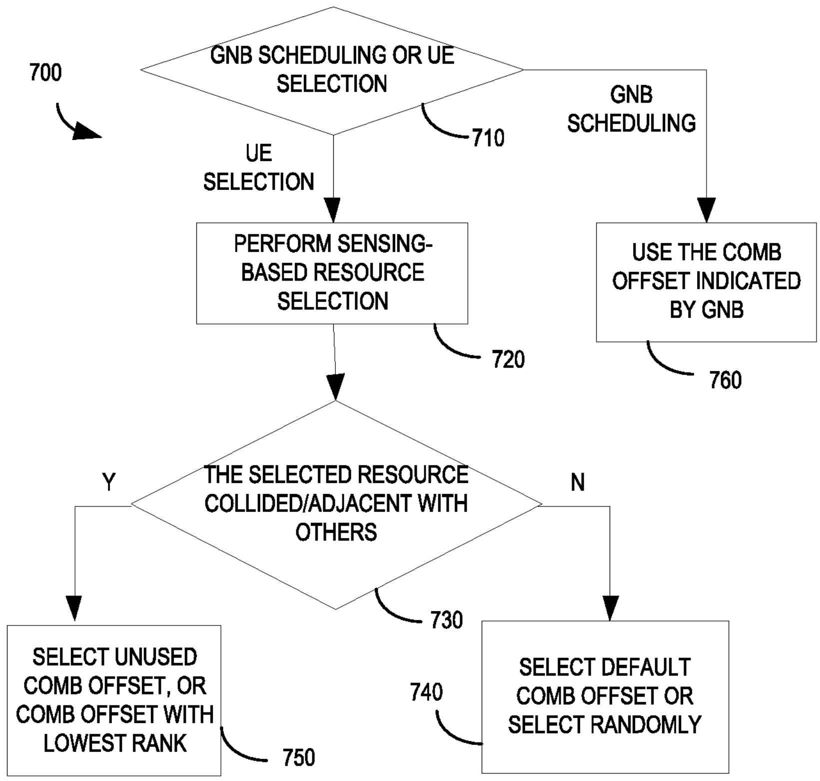
700
GNB SCHEDULING OR UE SELECTION
710
UE SELECTION
GNB SCHEDULING
PERFORM SENSING-BASED RESOURCE SELECTION
720
USE THE COMB OFFSET INDICATED BY GNB
760
THE SELECTED RESOURCE COLLIDED/ADJACENT WITH OTHERS
730
Y
N
SELECT UNUSED COMB OFFSET, OR COMB OFFSET WITH LOWEST RANK
750
SELECT DEFAULT COMB OFFSET OR SELECT RANDOMLY
740

FIG. 7

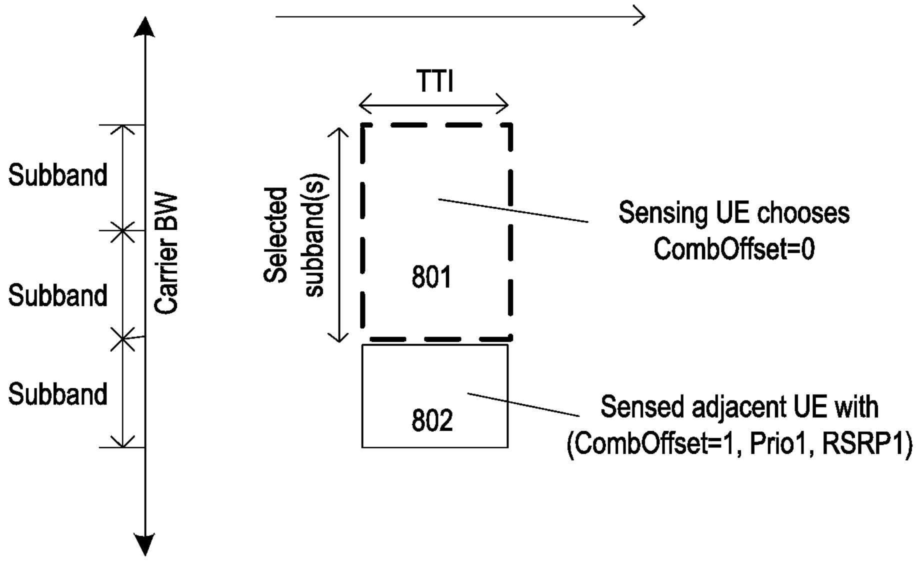
TTI
Subband
Subband
Subband
Carrier BW
Selected subband(s)
801
Sensing UE chooses CombOffset=0
802
Sensed adjacent UE with (CombOffset=1, Prio1, RSRP1)

FIG. 8

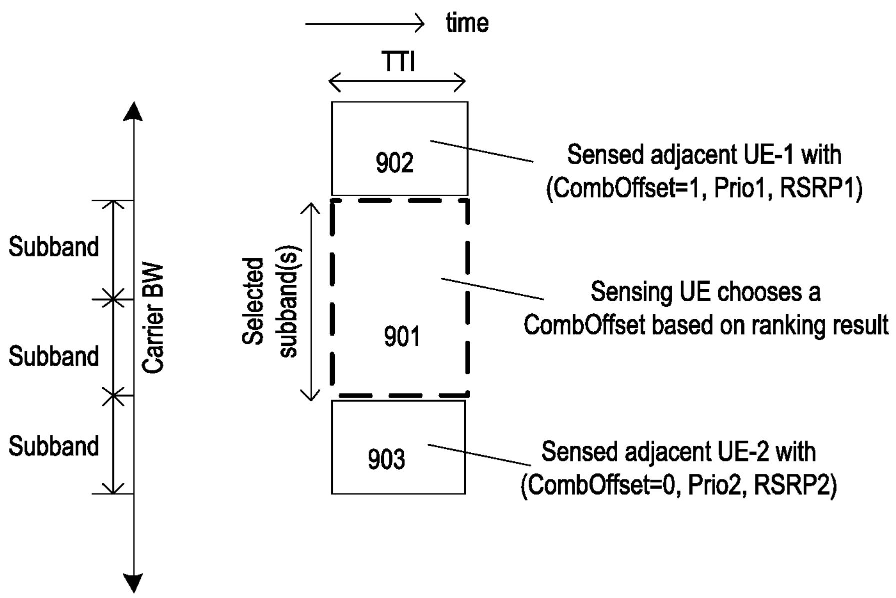
time
TTI
902
Sensed adjacent UE-1 with
(CombOffset=1, Prio1, RSRP1)
Subband
Subband
Subband
Carrier BW
Selected subband(s)
901
Sensing UE chooses a
CombOffset based on ranking result
903
Sensed adjacent UE-2 with
(CombOffset=0, Prio2, RSRP2)

FIG. 9

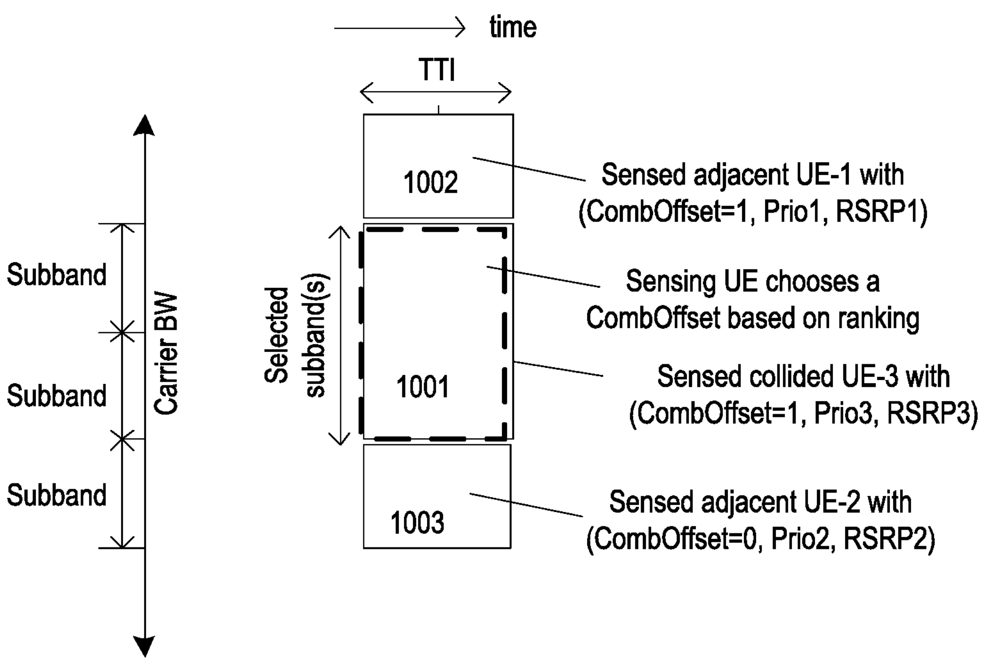
time
TTI
1002
Sensed adjacent UE-1 with
(CombOffset=1, Prio1, RSRP1)
Subband
Subband
Subband
Carrier BW
Selected subband(s)
1001
Sensing UE chooses a
CombOffset based on ranking
Sensed collided UE-3 with
(CombOffset=1, Prio3, RSRP3)
1003
Sensed adjacent UE-2 with
(CombOffset=0, Prio2, RSRP2)

FIG. 10

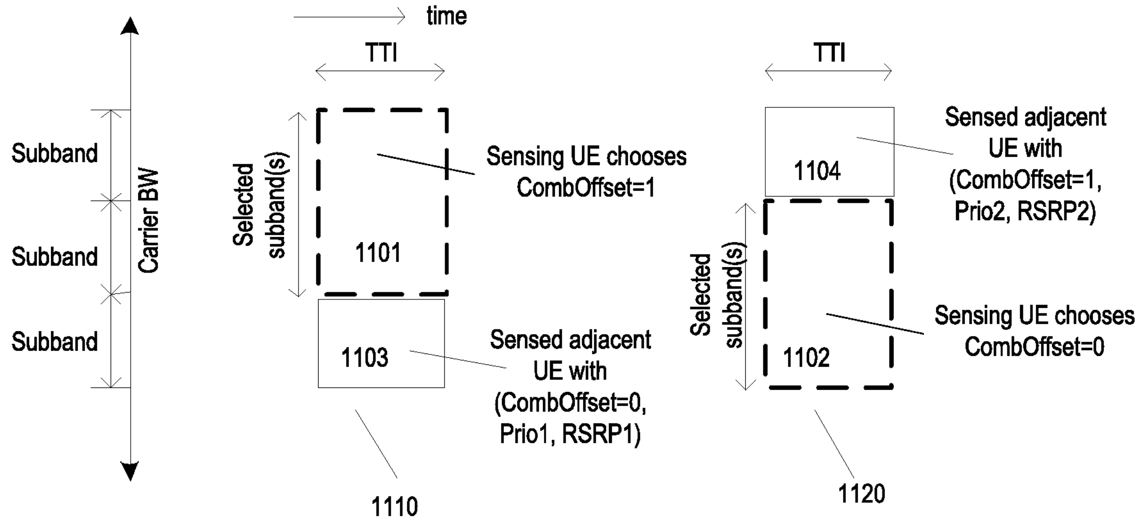
time
TTI
TTI
Subband
Subband
Subband
Carrier BW
Selected subband(s)
Sensing UE chooses CombOffset=1
1101
1103
Sensed adjacent UE with (CombOffset=0, Prio1, RSRP1)
1110
1104
Sensed adjacent UE with (CombOffset=1, Prio2, RSRP2)
Selected subband(s)
Sensing UE chooses CombOffset=0
1102
1120

FIG. 11

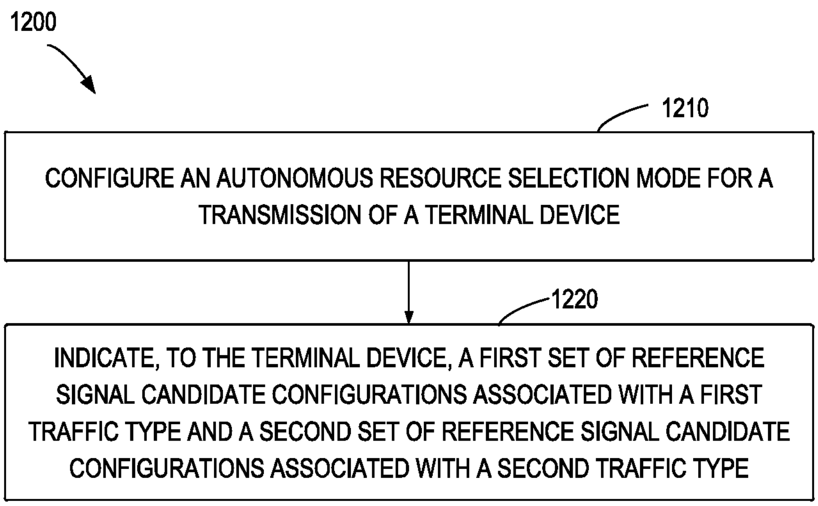
1200
1210
CONFIGURE AN AUTONOMOUS RESOURCE SELECTION MODE FOR A TRANSMISSION OF A TERMINAL DEVICE
1220
INDICATE, TO THE TERMINAL DEVICE, A FIRST SET OF REFERENCE SIGNAL CANDIDATE CONFIGURATIONS ASSOCIATED WITH A FIRST TRAFFIC TYPE AND A SECOND SET OF REFERENCE SIGNAL CANDIDATE CONFIGURATIONS ASSOCIATED WITH A SECOND TRAFFIC TYPE

FIG. 12

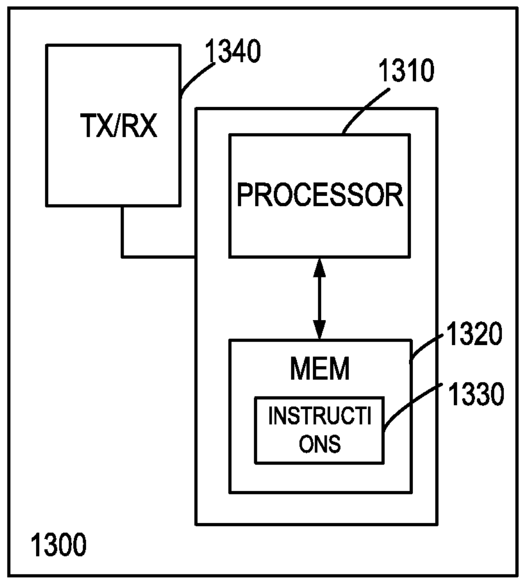

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/101702

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/08(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04B

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)

CNABS;CNTXT;CNKI;WOTXT;USTXT;VEN:channel, sens+, resourc+, select+, v2x, v2v, referece signal?, RS, demodulat+, DMRS, periodic+, aperiodic+, configurat+, offset

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017196159 A2 (SAMSUNG ELECTRONICS CO., LTD.) 16 November 2017 (2017-11-16) description, paragraphs 3, 4, 90-108 and 177-179	1-63
A	WO 2018021767 A1 (SAMSUNG ELECTRONICS CO., LTD.) 01 February 2018 (2018-02-01) the whole document	1-63
A	CN 107852685 A (LG ELECTRONICS INC.) 27 March 2018 (2018-03-27) the whole document	1-63
A	CN 107809802 A (SHANGHAI NOKIA BELL CO., LTD.) 16 March 2018 (2018-03-16) the whole document	1-63

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
22 April 2019	**07 May 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**GENG,Wenhui**
Facsimile No. **(86-10)62019451**	Telephone No. **62412153**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/101702

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2017196159	A2	16 November 2017	WO	2017196159	A3	26 July 2018
				US	2017332390	A1	16 November 2017
WO	2018021767	A1	01 February 2018		None		
CN	107852685	A	27 March 2018	US	2018220388	A1	02 August 2018
				WO	2017007285	A1	12 January 2017
				EP	3322234	A1	16 May 2018
				JP	2018525894	A	06 September 2018
				EP	3322234	A4	06 March 2019
CN	107809802	A	16 March 2018		None		