COMMUNICATION APPARATUSES AND COMMUNICATION METHODS FOR UTILIZATION OF RELEASED RESOURCE

TECHNICAL FIELD

[1] The following disclosure relates to communication apparatuses and communication methods for New Radio (NR) communications, and more particularly to communication apparatuses and communication methods for utilization of released resource.

BACKGROUND

[2] V2X communication allows vehicles to interact with public roads and other road users, and is thus considered a critical factor in making autonomous vehicles a reality.

[3] To accelerate this process, 5G NR based V2X communications (interchangeably referred to as NR V2X communications) is being discussed by the 3rd Generation Partnership Project (3GPP) to identify technical solutions for advanced V2X services, through which vehicles (i.e. interchangeably referred to as communication apparatuses or user equipments (UEs) that support V2X applications) can exchange their own status information through sidelink (SL) with other nearby vehicles, infrastructure nodes and/or pedestrians. The status information includes information on position, speed, heading, etc.

[4] In such V2X communications, there are at least two SL resource allocation modes being discussed by the 3GPP. In resource allocation Mode 1, SL resource(s) to be used by a UE for SL transmissions are scheduled by a base station (BS). In resource allocation Mode 2, the UE determines, i.e. the BS does not schedule, SL transmission resources within the SL resources configured by the BS/network or pre-configured SL resources. The 3GPP study on resource allocation also considers sensing and resource selection procedures for a Mode 2(a), in the context of a semi-persistent scheme where resource(s) are selected for multiple transmissions of different transmission blocks (TBs) and a dynamic scheme where resource(s) are selected for each TB transmission.

[5] In the 3GPP RAN WG1 #96b meeting in Xi'an, the following items were considered:

- NR V2X supports an initial transmission of a TB without reservation, based on sensing and resource selection procedure.
- NR V2X supports reservation of a sidelink resource for an initial transmission of a TB at least by a sidelink control information (SCI) associated with a different TB, based on sensing and resource selection procedure. This functionality can be enabled/disabled by (pre-)configuration.
- For further study (FFS): Standalone Physical Sidelink Control Channel (PSCCH) transmissions for resource reservations are supported in NR V2X.

[6] In the 3GPP RAN WG1 #97 meeting in Reno, the following items were considered:

- NR V2X Mode-2 supports resource reservation for feedback-based Physical Sidelink Shared Channel (PSSCH) retransmissions by signaling associated with a prior transmission of a same TB.
    - FFS: impact on subsequent sensing and resource selection procedures.
    - At least from the transmitter perspective of above-mentioned TB, usage of Hybrid Automatic Repeat Request (HARQ) feedback for release of unused resource(s) is supported.

[7] However, there has been no discussion on communication apparatuses and methods for utilization of released resource.

[8] There is thus a need for communication apparatuses and methods that provide feasible technical solutions for utilization of released resource. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[9] Non-limiting and exemplary embodiment facilitates providing communication apparatuses and methods for utilization of released resource.

[10] According to a first embodiment of the present disclosure, there is provided a communication apparatus comprising: a receiver which, in operation, receives release information relating to a reserved resource from another communication apparatus, the reserved resource being reserved for a transmission from the another communication apparatus; and circuitry which, in operation, selects a resource from a plurality of resource candidates when the communication apparatus is to do a subsequent transmission, wherein the plurality of resource candidates includes the reserved resource.

[11] According to a second embodiment of the present disclosure, there is provided a communication apparatus comprising: circuitry which, in operation, determines release information relating to a reserved resource, the reserved resource being reserved for a transmission from the communication apparatus; and a transmitter which, in operation, transmits the release information to another communication apparatus.

[12] According to a third embodiment of the present disclosure, there is provided a communication method comprising: receiving release information relating to a reserved resource, the reserved resource being reserved for a transmission from a communication apparatus; and selecting a resource from a plurality of resource candidates when a subsequent transmission is to be done, wherein the plurality of resource candidates includes the reserved resource.

[13] According to a fourth embodiment of the present disclosure, there is provided a communication method comprising: determining release information relating to a reserved resource, the reserved resource being reserved for a transmission; and transmitting the release information to a communication apparatus.

[14] It should be noted that general or specific embodiments may be implemented as a system, a method, an integrated circuit, a computer program, a storage medium, or any selective combination thereof.

[15] Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[16] Embodiments of the disclosure will be better understood and readily apparent to one of ordinary skilled in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[17] Fig. 1 depicts a schematic diagram 100 illustrating how a resource may be reserved for a future transmission in V2X communications.

[18] Fig. 2 depicts a schematic diagram 200 illustrating how a released resource may be utilised by way of an Operation A according to various embodiments.

[19] Fig. 3 depicts a schematic diagram 300 illustrating how a released resource may be utilised by way of an Operation B according to various embodiments.

[20] Fig. 4 shows a flow diagram 400 illustrating how a physical (PHY) layer performs sensing in Operation A and B according to various embodiments.

[21] Fig. 5 shows a flow diagram 500 illustrating how a PHY layer performs step 404 of flow diagram 400 in Operation A according to various embodiments.

[22] Fig. 6 shows a flow diagram 600 illustrating how a medium access control (MAC) layer performs release judgement and selection in Operation A according to various embodiments.

[23] Fig. 7 shows a flow diagram 700 illustrating how a PHY layer performs step 404 of flow diagram 400 in Operation B according to various embodiments.

[24] Fig. 8 shows a flow diagram 800 illustrating how a MAC layer performs selection in Operation B and Operation C according to various embodiments.

[25] Fig. 9 shows a flow diagram 900 illustrating how a MAC layer performs prioritisation of a released resource according to various embodiments.

[26] Fig. 10 depicts a schematic diagram 1000 illustrating PHY layer configuration for Operation A, B and C according to various embodiments.

[27] Fig. 11 shows a flow diagram 1100 illustrating a communication method according to various embodiments.

[28] Fig. 12 shows a flow diagram 1200 illustrating a communication method according to various embodiments.

[29] Fig. 13 shows a schematic example of communication apparatus in accordance with various embodiments. The communication apparatus may be implemented as an UE or a gNB/base station and configured for utilising release resources in accordance with various embodiments of the present disclosure.

[30] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help to improve understanding of the present embodiments.

DETAILED DESCRIPTION

[31] Some embodiments of the present disclosure will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[32] As mentioned above, usage of HARQ feedback for release of unused resource(s) is supported at least from a transmitting UE's perspective of a concerned TB. However, no additional signaling is defined for the purpose of release of unused resources by the transmitting UE. Further, the behavior of the receiver UE(s) of this TB and other UEs are FFS.

[33] PHY layer sensing and reporting of resources in LTE V2X are defined in the TS36.213 section 14.1.1.6 as per the following steps:

1) A candidate single-subframe resource for PSSCH transmission $R_{x,y}$ is defined as a set of L_{subCH} contiguous sub-channels with sub-channel *x+j* in subframe t_y^{SL} where $j = 0,...,L_{subCH}-1$. The UE shall assume that any set of L_{subCH} contiguous sub-channels included in the corresponding PSSCH resource pool (described in 14.1.5) within the time interval $[n+T_1, n+T_2]$ corresponds to one candidate single-subframe resource, where selections of T_1 and T_2 are up to UE implementations under $T_1 \le 4$ and $T_{2min}(prio_{TX}) \le T_2 \le 100$, if $T_{2min}(prio_{TX})$ is provided by higher layers for $prio_{TX}$, otherwise $20 \le T_2 \le 100$. UE selection of T_2 shall fulfil the latency requirement. The total number of the candidate single-subframe resources is denoted by M_{total}.

2) The UE shall monitor subframes $t^{SL}_{n'-10\times P_{step}}, t^{SL}_{n'-10\times P_{step}+1}, \ldots, t^{SL}_{n'-1}$ except for those in which its transmissions occur, where $t^{SL}_{n'} = n$ if subframe n belongs to the set $\left(t_0^{SL}, t_1^{SL}, ..., t_{T_{max}}^{SL}\right)$, otherwise subframe $t^{SL}_{n'}$ is the first subframe after subframe n belonging to the set $\left(t_0^{SL}, t_1^{SL}, ..., t_{T_{max}}^{SL}\right)$. The UE shall perform the behaviour in the following steps based on PSCCH decoded and S-RSSI measured in these subframes.

3) The parameter $Th_{a,b}$ is set to the value indicated by the i-th *SL-ThresPSSCH-RSRP* field in *SL-ThresPSSCH-RSRP-List* where $i = a*8+b+1$.

4) The set S_A is initialized to the union of all the candidate single-subframe resources. The set S_B is initialized to an empty set.

5) The UE shall exclude any candidate single-subframe resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

   - the UE has not monitored subframe t_z^{SL} in Step 2.

   - there is an integer *j* which meets $y + j \times P'_{rsvp_TX} = z + P_{step} \times k \times q$ where *j*=0, 1, …, $C_{resel}-1$, $P'_{rsvp_TX} = P_{step} \times P_{rsvp_TX} / 100$, *k* is any value allowed by the higher layer parameter *restrictResourceReservationPeriod* and *q*=1,2,…,Q. Here, $Q = \frac{1}{k}$ if $k < 1$ and $n' - z \le P_{step} \times k$, where $t^{SL}_{n'} = n$ if subframe *n* belongs to the set $t_0^{SL}, t_1^{SL}, ..., t_{T_{max}}^{SL}$, otherwise subframe $t^{SL}_{n'}$ is the first subframe belonging to the set $t_0^{SL}, t_1^{SL}, ..., t_{T_{max}}^{SL}$ after subframe *n*; and $Q = 1$ otherwise.

6) The UE shall exclude any candidate single-subframe resource $R_{x,y}$ from the set S_A if it meets all the following conditions:

- the UE receives an SCI format 1 in subframe t_m^{SL} , and "Resource reservation" field and "Priority" field in the received SCI format 1 indicate the values $P_{\text{rsvp_RX}}$ and $prio_{RX}$, respectively according to Subclause 14.2.1.

- PSSCH-RSRP measurement according to the received SCI format 1 is higher than $Th_{prio_{TX},prio_{RX}}$.

- the SCI format received in subframe t_m^{SL} or the same SCI format 1 which is assumed to be received in subframe(s) $t_{m+q\times P_{step}\times P_{rsvp_RX}}^{SL}$ determines according to 14.1.1.4C the set of resource blocks and subframes which overlaps with $R_{x,y+j\times P'_{rsvp_TX}}$ for *q*=1, 2, …, *Q* and *j*=0, 1, …, $C_{resel}-1$. Here, $Q=\frac{1}{P_{rsvp_RX}}$ if $P_{rsvp_RX}<1$ and $n'-m\le P_{step}\times P_{rsvp_RX}$, where $\text{t}_{n'}^{\text{SL}}=n$ if subframe n belongs to the set $\left(t_0^{SL},t_1^{SL},...,t_{T_{\max}}^{SL}\right)$, otherwise subframe $\text{t}_{n'}^{\text{SL}}$ is the first subframe after subframe n belonging to the set $\left(t_0^{SL},t_1^{SL},...,t_{T_{\max}}^{SL}\right)$; otherwise $Q=1$.

7) If the number of candidate single-subframe resources remaining in the set S_A is smaller than $0.2\cdot M_{\text{total}}$, then Step 4 is repeated with $Th_{a,b}$ increased by 3 dB.

8) For a candidate single-subframe resource $R_{\text{x,y}}$ remaining in the set S_A, the metric $E_{\text{x,y}}$ is defined as the linear average of S-RSSI measured in sub-channels *x+k* for $k=0,...,L_{\text{subCH}}-1$ in the monitored subframes in Step 2 that can be expressed by $t_{y-P_{step}*j}^{SL}$ for a non-negative integer *j* if $P_{rsvp_TX}\ge 100$, and $\text{t}_{y-P'_{rsvp_TX}*j}^{\text{SL}}$ for a non-negative integer *j* otherwise.

9) The UE moves the candidate single-subframe resource $R_{\text{x,y}}$ with the smallest metric $E_{\text{x,y}}$ from the set S_A to S_B. This step is repeated until the number of candidate single-subframe resources in the set S_B becomes greater than or equal to $0.2\cdot M_{\text{total}}$,

10) When the UE is configured by upper layers to transmit using resource pools on multiple carriers, it shall exclude a candidate single-subframe resource $R_{\text{x,y}}$ from S_B if the UE does not support transmission in the candidate single-subframe resource in the carrier under the assumption that transmissions take place in other carrier(s) using the already selected resources due to its limitation in the number of simultaneous transmission carriers, its limitation in the supported carrier combinations, or interruption for RF retuning time [10].

The UE shall then report set S_B to higher layers.

[34] Fig. 1 depicts a schematic diagram 100 illustrating how a resource may be reserved for a future transmission in V2X communications. For example, a

transmitting UE (Tx UE) may perform a SL transmission of a TB using a resource#1 102 to receiving UE(s) (Rx UE(s)).

[35] The Tx UE and Rx UE(s) may include, for example, communication modules integrated or installed in vehicles subscribed to communication services of one or more telecommunications / Public Land Mobile Network (PLMN) operators. The Tx UE and Rx UE(s) may be subscribed to a telecommunication / PLMN operator operator and communicates with a base station of the telecommunication operator. The base station may be a next generation NodeB (gNB). It can be appreciated by those skilled in the art that the base station 102 can also be a ng-eNB, and may be connected via the NG interface to a 5G core network.

[36] The SL transmission of the TB may be via a Physical Sidelink Shared Channel (PSSCH) and its corresponding control information SCI may be transmitted via a Physical Sidelink Control Channel (PSCCH). Accordingly, as shown in Fig. 1, a SCI#1 in resource#1 102 indicates a current transmission (SCI#1+PSSCH#1) in resource#1 102, and also reserves a resource#2 104 for possible future transmission (SCI#2+PSSCH#2) for the same target receiver(s) i.e. the Rx UE(s).

[37] Under certain circumstances, the Tx UE may cancel its future transmission of SCI#2+PSSCH#2, and the reserved resource#2 104 will then be treated as released. For example, when PSSCH#2 is a possible HARQ retransmission of PSSCH#1, the resource#2 104 can be released if PSSCH#1 is received successfully.

[38] Thus far, 3GPP has only discussed the signalling for releasing a reserved resource for HARQ retransmission. However, it is still not clear how to utilize the released resource (i.e., the behavior of the Rx UE(s), the Tx UE and other UEs of the current transmission).

[39] Therefore, the present invention proposes an improved communication procedure such that the released resource may be utilized by the Rx UE(s), Tx UE and other UEs.

[40] In the following paragraphs, certain exemplifying embodiments are explained with reference to a V2X communications mechanism that advantageously allows a released resource to be utilised by Rx UE(s), Tx UE and other UEs of a current transmission.

[41] For a sidelink resource reserved by a UE for a future transmission (i.e. after a current transmission has occurred), when the reserved resource is released by the UE, the release information/signalling is made known to certain UEs (e.g., Tx UE, or Tx UE & Rx UEs). The released resource may then be included during resource selection by the UE(s) which are aware of the release information, for possible subsequent transmission from the UE(s). As the reservation is known to all UEs which receives/decodes the control information in the current transmission, these UE will exclude the reserved resource during their sensing procedures. Advantageously, there will be lower chance of over-the-air collisions on the released resource.

[42] Referring back to Fig. 1, a Tx UE may perform a sidelink transmission of TB#1 in resource 102. The SCI#1 in resource#1 102 indicates the current transmission (SCI#1+PSSCH#1) in resource#1 102, and also reserves resource#2 104, which may be used as a future transmission such as, for example, a future HARQ retransmission, for the same target receiver as PSSCH#1. The transmission of TB#1 in resource#1 102 can be a unicast to another UE, or groupcast to a group of UEs, or a broadcast. For all UEs (not only the target receiver of PSSCH#1) to receive SCI#1 where the reference signal received power (RSRP) of SCI#1 is higher than $Th_{a,b}$, the future transmission in resource#2 is reserved. The Tx UE is aware that the resource#2 104 can be released when the transmission of TB#1 in resource#1 102 is successfully received by the receiver UEs, for example by receiving a release information through a Physical Sidelink Feedback Channel (PSFCH) from the receiver UEs. The release information may be any explicit or implicit signal for informing that the reserved resource can be released, such as an acknowledgement feedback (for example, HARQ-ACK or non-NACK) from the receiver UEs to the Tx UE. The Tx UE may also determine and transmit release information to other UEs to inform that the resource#2 104 is released, so that these UEs can include the resource#2 104 in their resource selection for their own transmissions. In various embodiments, the release information may be generated from an associated

base station or gNB to the Tx UE and Rx UE(s), for example in the case of Mode-1 transmissions.

[43] Fig. 2 depicts a schematic diagram 200 illustrating how a released resource may be utilised by way of an Operation A according to various embodiments, after a UE is aware of release information relating to a reserved resource, the reserved resource being one which may be reserved for a transmission. For example, the Tx UE as described in Fig. 1 may reuse the released resource#2 104 for a subsequent transmission of another TB, for example a TB#2. Under Operation A, the PHY layer 202 of Tx UE performs sensing procedures for candidate resources from an initial set S_A and then reports a set of candidate resources S_B to the MAC layer 204 of the Tx UE. The initial set of S_A contains all M_{total} candidate resources for subsequent transmission of TB#2. The PHY layer 202 may perform, during the sensing procedures, a step of resource exclusion such that the reserved resource#2 104 will not be excluded from the initial set S_A if the reserved resource#2 104 is within S_A. Conversely, the reserved resource#2 104 will be excluded from the initial set S_A if the reserved resource#2 104 is not within S_A. The set S_B that is reported to the MAC layer 204 contains ≥ 20%* M_{total} candidate resources with the lowest RSRP from the remaining set S_A after the resource exclusion step.

[44] Thereafter, the MAC layer 204 performs release judgement and resource selection. Release judgement is performed on reserved candidate resources, wherein the MAC layer 204 judges whether or not a reserved candidate resource is released based on release information of the reserved candidate resource. The release information may be determined or generated by the Tx UE (i.e. for a candidate resource that is reserved for a future transmission from the TX UE, such as resource#2 104), or received from the Rx UE(s) or an associated base station. For example, if S_B contains resource#2 104, and the resource#2 104 is judged as released by MAC layer:

- The contiguous candidate resource containing resource#2 104 (if there is sufficient size and latency) may be prioritized by the MAC layer 204 during the resource selection for subsequent transmission of TB#2
- The resource#2 104 may be partially used, solely used, or used conjugately with other contiguous resources
- Otherwise, the MAC layer 204 may perform a random selection of a resource from S_B for the transmission of TB#2.

[45] Fig. 3 depicts a schematic diagram 300 illustrating how a released resource may be utilised by way of an Operation B according to various embodiments. For example, the Tx UE as described in Fig. 1 may reuse the released resource#2 104 for a subsequent transmission of another TB, for example a TB#2. Under Operation B, the PHY layer 302 of Tx UE performs sensing procedures and release judgement for candidate resources from an initial set S_A and then reports a set of candidate resources S_B to the MAC layer 304 of the Tx UE. The initial set of S_A contains all M_{total} candidate resources for subsequent transmission of TB#2. The PHY layer 302 may perform, during the sensing procedures, a step of resource exclusion such that the reserved resource#2 104 will not be excluded from the initial set S_A if the reserved resource#2 104 is within S_A and if the reserved resource#2 104 is judged as released by the PHY layer 302. Conversely, the reserved resource#2 104 will be excluded from the initial set S_A even if the reserved resource#2 104 is within S_A, but the reserved resource#2 104 is judged as non-released by the PHY layer 302. Release judgement is performed on reserved candidate resources, wherein the PHY layer 302 judges a reserved candidate resource as released based on release information of the reserved candidate resource. The release information may be determined by the Tx UE (i.e. for a candidate resource that is reserved for a future transmission from the TX UE, such as resource#2 104), or received from the Rx UE(s) or an associated base station. The set S_B that is reported to the MAC layer 304 contains ≥ 20%* M_{total} candidate resources with the lowest RSRP from the remaining set S_A after the resource exclusion step.

[46] Thereafter, the MAC layer 304 performs resource selection. For example, If S_B contains resource#2 104:

- The contiguous candidate resource containing resource#2 104 (if there is sufficient size and latency) may be prioritized by MAC layer 304 during the resource selection for subsequent transmission of TB#2
- The resource#2 104 may be partially used, solely used, or used conjugately with other contiguous resources
- Otherwise, the MAC layer 304 may perform a random selection of a resource from S_B for the transmission of TB#2.

[47] Further, a released resource may be utilised by way of an Operation C according to various embodiments, after a UE is aware of release information

relating to a reserved resource. For example, the Tx UE as described in Fig. 1 may reuse the released resource#2 104 for a subsequent transmission of another TB, for example a TB#2. Under Operation C, the set of candidate resources S_B may be provided to the MAC layer of the Tx UE by pre-configuration, RRC or MAC. Thereafter, the MAC layer performs resource selection. For example, If S_B contains resource#2 104:

- The contiguous candidate resource containing resource#2 104 (if there is sufficient size and latency) may be prioritized by MAC layer during the resource selection for subsequent transmission of TB#2
- The resource#2 104 may be partially used, solely used, or used conjugately with other contiguous resources
- Otherwise, the MAC layer may perform a random selection of a resource from S_B for the transmission of TB#2.

[48] Fig. 4 shows a flow diagram 400 illustrating how a PHY layer, such as the PHY layer 202 and 302, performs sensing in Operation A and B respectively according to various embodiments. At step 402, the PHY layer senses a set S_A with all M_{total} candidate resources. At step 404, the PHY layer performs an iteration of resource exclusion such that candidate resources are excluded from set S_A if certain conditions are met. The conditions for exclusion differ for Operation A and Operation B, since the PHY layer performs release judgement in Operation B but does not do so in Operation A. At step 406, it is determined whether the number of candidate resources remaining in S_A after the resource exclusion step 404 is <0.2 M_{total}. If it is determined that the number of candidate resources remaining in S_A after the resource exclusion step 404 is <0.2 M_{total}, the process proceeds to step 414 where the $Th_{a,b}$ is increased by 3dB, and then proceeds back to step 404 for a repeated procedure of the resource exclusion process, until it is determined at step 406 that the set S_A contains ≥ 20%* M_{total} candidate resources.

[49] Thereafter, the process proceeds to a sorting step 408 where candidate resources with lowest RSRP are moved from S_A to S_B. In various embodiments, for step 408 under Operation B, the resource#2 104 may be given more weightage to be included in the set S_B, when the resource#2 104 is excluded from S_A, and satisfy the amount of lowest RSPR of 20% of M_{total}. In various embodiments, for step 408 under Operation A or B, the resource#2 104 may be

given more weightage to be included in the set S_B, when the resource#2 104 is not excluded from S_A, but not satisfy the amount of lowest RSPR of 20% of M_{total}.

[50] At step 410, it is determined whether the number of candidate resources in set S_B <0.2 M_{total}. If it is determined that the number of candidate resources in set S_B is <0.2 M_{total}, the process repeats sorting step 408 until the number of candidate resources in set S_B is ≥0.2 M_{total}. At step 412, the set S_B is reported to the higher layers, for example the MAC layer 204 or MAC layer 304.

[51] Fig. 5 shows a flow diagram 500 illustrating how a PHY layer, such as the PHY layer 202, performs step 404 of flow diagram 400 in Operation A according to various embodiments. At step 502, the PHY layer 202 determines whether a candidate resource is reserved. If it is determined that the candidate resource is not reserved, the process proceeds to step 508 wherein the candidate resource is not excluded from set S_A. If it is determined that the candidate resource is reserved, the process proceeds to step 504 to determine whether the candidate resource is reserved for the concerned UE, which in this case is the Tx UE. If it is determined that the candidate resource is reserved for the Tx UE, the process proceeds to step 508 wherein the candidate resource is not excluded from set S_A. Otherwise, the process proceeds to step 506 where the candidate resource is excluded. Advantageously, step 508 ensures a lower chance of over-the-air collisions on the candidate resource.

[52] Fig. 6 shows a flow diagram 600 illustrating how a MAC layer, such as the MAC layer 204, performs release judgement and selection in Operation A according to various embodiments. At step 602, a set S_B is reported to the MAC layer 204. At step 604, it is determined whether the set S_B contain a reserved resource, for example the reserved resource#2 104. If it is determined that the set S_B does not contain a reserved resource, the process proceeds to step 612 wherein the MAC layer 204 performs a random selection of resources from the set S_B for transmission of TB#2. Otherwise, the process proceeds to release judgement step 606, where it is judged whether the reserved resource is released. Release judgement is performed on reserved candidate resources, wherein the MAC layer 204 judges whether or not a reserved candidate resource is released based on release information of the reserved candidate resource. The release information may be determined or generated by the Tx UE (i.e. for a candidate resource that is reserved for a future transmission from the TX UE,

such as resource#2 104), or received from the Rx UE(s) or an associated base station. If the candidate resource is not judged as released, the process proceeds to step 612 wherein the MAC layer 204 performs a random selection of resources from the set S_B for transmission of TB#2. If the candidate resource is judged as released, the process proceeds to step 608 where it is determined whether the candidate resource size meets Quality of Service (QoS) requirements. If it is determined that the candidate resource size does not meet QoS requirements, the process proceeds to step 612 wherein the MAC layer 204 performs a random selection of resources from the set S_B for transmission of TB#2. Otherwise, the process proceeds to step 610 wherein the MAC layer 204 prioritises the released resource over the other candidate resources when selecting a resource from the set S_B for transmission of the TB#2. Advantageously, the Tx UE can reuse the released resource#2 104 for a future transmission.

[53] Fig. 7 shows a flow diagram 700 illustrating how a PHY layer, such as the PHY layer 302, performs step 404 of flow diagram 400 in Operation B according to various embodiments. At step 702, the PHY layer 302 determines whether a candidate resource is reserved. If it is determined that the candidate resource is not reserved, the process proceeds to step 708 wherein the candidate resource is not excluded from set S_A. If it is determined that the candidate resource is reserved, the process proceeds to step 704 to determine whether the candidate resource is reserved for the concerned UE, which in this case is the Tx UE. If it is determined that the candidate resource is not reserved for the Tx UE, the process proceeds to step 710 wherein the candidate resource is excluded from set S_A. Otherwise, the process proceeds to release judgement step 706, where it is judged whether the reserved candidate resource is released. Release judgement is performed on reserved candidate resources, wherein the PHY layer 302 judges whether or not a reserved candidate resource is released based on release information of the reserved candidate resource. The release information may be determined or generated by the Tx UE (i.e. for a candidate resource that is reserved for a future transmission from the TX UE, such as resource#2 104), or received from the Rx UE(s) or an associated base station. If the candidate resource is judged as released, the process proceeds to step 708 wherein the candidate resource is not excluded from set S_A. Otherwise, the process proceeds to step 710 wherein the candidate resource is excluded from set S_A.

Advantageously, step 704 ensures a lower chance of over-the-air collisions on the candidate resource.

[54] Fig. 8 shows a flow diagram 800 illustrating how a MAC layer, for example the MAC layer 304, performs resource selection in Operation B and Operation C according to various embodiments. At step 802, a set S_B is reported to the MAC layer 304. At step 804, it is determined whether the set S_B contain a reserved resource, for example the reserved resource#2 104. If it is determined that the set S_B does not contain a reserved resource, the process proceeds to step 810 wherein the MAC layer 304 performs a random selection of resources from the set S_B for transmission of TB#2. Otherwise, the process proceeds to step 806 where it is determined whether the candidate resource size meets QoS requirements. If it is determined that the candidate resource size does not meet QoS requirements, the process proceeds to step 810 wherein the MAC layer 304 performs a random selection of resources from the set S_B for transmission of TB#2. Otherwise, the process proceeds to step 808 wherein the MAC layer 304 prioritises the reserved resource#2 104 over the other candidate resources when selecting a resource from the set S_B for transmission of the TB#2. Advantageously, the Tx UE can reuse the released resource#2 104 for a future transmission.

[55] Fig. 9 shows a flow diagram 900 illustrating how a MAC layer, for example the MAC layer 204 or 304, performs prioritisation of a released resource for Operation A, B and C according to various embodiments. The prioritisation is performed in step 610 of flow diagram 600 and step 808 in flow diagram 800. At step 902, it is determined whether the resource size of reserved resource#2 104 is sufficient for the TB#2 transmission. If it is determined that the size is not sufficient, the process proceeds to step 906 wherein the MAC layer 204 or 304 uses the reserved resource#2 104 conjugately with other contiguous resources for transmission of the TB#2. The MAC layer 204 or 304 may perform, at step 908, a random selection from set S_B for the other contiguous resources. On the other hand, if it is determined that the size is sufficient, the process proceeds to step 904 wherein the reserved resource#2 104 is solely used or partially used for the transmission of the TB#2. Advantageously, the released resource#2 104 is prioritised for reuse for the transmission of TB#2.

[56] It will be appreciated that for the resource selection performed by the MAC layer, the released resource#2 104 may also be treated with equal probability as other candidate resources, especially when large number of UEs are aware of the release information for released resource#2 104.

[57] Fig. 10 depicts a schematic diagram 1000 illustrating PHY layer configuration for Operation A, B and C according to various embodiments. In Operation A and B, the PHY layer (i.e. PHY layer 202 and 302) is configured to perform sensing of candidate resources and report the resulting set S_B to the MAC layer (i.e. the MAC layer 204 and 304). In Operation C, however, the PHY layer is not configured to assist in resource sensing.

[58] It will be appreciated that Operation A, B and C can also be applied to the Rx UE(s) or other UE(s) for their own future transmissions when the Rx UE(s) or other UE(s) are aware that resource#2 104 is released, for example when release information of the resource#2 104 is transmitted from the Tx UE to the Rx UE(s) or other UE(s). This applies whether the current transmission (i.e. the transmission of TB#1) is a unicast, groupcast or broadcast to the Rx UE(s). In the case of groupcast, it may be preferable that the number of Rx UEs is small, otherwise there can be more chance of collision in among the Rx UE(s). Further, the above mentioned operations can also apply to Mode-1 transmissions if the gNB grant resources for both initial transmission (i.e. resource#1) and HARQ re-transmission (i.e. resource#2) of the TB sent by the Tx UE. In various embodiments where a released resource is not within the transmission resource pool of the Rx UE(s) or other UEs, no additional behaviour may be defined for the Rx UE(s) and other UEs, and only the Tx UE is able to use the released resource.

[59] Fig. 11 shows a flow diagram 1100 illustrating a communication method according to various embodiments. In step 1102, release information relating to a reserved resource is received, the reserved resource being reserved for a transmission from a communication apparatus. In step 1104, a resource from a plurality of resource candidates is selected when a subsequent transmission is to be done, wherein the plurality of resource candidates includes the reserved resource.

[60] Fig. 12 shows a flow diagram 1200 illustrating a communication method according to various embodiments. In step 1202, release information relating to a reserved resource is determined, the reserved resource being reserved for a transmission. In step 1204, the release information is transmitted to a communication apparatus.

[61] Fig. 13 shows a schematic, partially sectioned view of the communication apparatus 1300 that can be implemented for establishing the V2X communications in accordance with various embodiments as shown in Figs. 1 to 12. The communication apparatus 1300 may be implemented as a UE or a base station according to various embodiments.

[62] Various functions and operations of the communication apparatus 1300 are arranged into layers in accordance with a hierarchical model. In the model, lower layers report to higher layers and receive instructions therefrom in accordance with 3GPP specifications. For the sake of simplicity, details of the hierarchical model are not discussed in the present disclosure.

[63] As shown in Fig. 13, the communication apparatus 1300 may include circuitry 1314, at least one radio transmitter 1302, at least one radio receiver 1304, and at least one antenna 1312 (for the sake of simplicity, only one antenna is depicted in Fig. 13 for illustration purposes). The circuitry 1314 may include at least one controller 1306 for use in software and hardware aided execution of tasks that the at least one controller 1306 is designed to perform, including control of communications with one or more other communication apparatuses in a wireless network. The circuitry 1314 may furthermore include at least one transmission signal generator 1308 and at least one receive signal processor 1310. The at least one controller 1306 may control the at least one transmission signal generator 1308 for generating signals (for example, a signal containing release information relating to a reserved resource) to be sent through the at least one radio transmitter 1302 to one or more other communication apparatuses and the at least one receive signal processor 1310 for processing signals (for example, a signal containing release information relating to a reserved resource) received through the at least one radio receiver 1304 from the one or more other communication apparatuses under the control of the at least one controller 1306. The at least one transmission signal generator 1308 and the at least one receive signal processor 1310 may be stand-alone modules

of the communication apparatus 1300 that communicate with the at least one controller 1306 for the above-mentioned functions, as shown in Fig. 13. Alternatively, the at least one transmission signal generator 1308 and the at least one receive signal processor 1310 may be included in the at least one controller 1306. It is appreciable to those skilled in the art that the arrangement of these functional modules is flexible and may vary depending on the practical needs and/or requirements. The data processing, storage and other relevant control apparatus can be provided on an appropriate circuit board and/or in chipsets. In various embodiments, when in operation, the at least one radio transmitter 1302, at least one radio receiver 1304, and at least one antenna 1312 may be controlled by the at least one controller 1306.

[64] The communication apparatus 1300, when in operation, provides functions required for utilization of a released resource. For example, the communication apparatus 1300 may be a UE, and the radio receiver 1304 may, in operation, receive release information relating to a reserved resource from another communication apparatus, the reserved resource being reserved for a transmission from the another communication apparatus. The circuitry 1314 may, in operation, select a resource from a plurality of resource candidates when the communication apparatus is to do a subsequent transmission, wherein the plurality of resource candidates includes the reserved resource.

[65] The release information may be received over a PSFCH. The circuitry 1314 may be further configured to exclude or not exclude the reserved resource from the plurality of resource candidates, wherein judgement for excluding or not excluding the reserved resource from the plurality of resource candidates is done by a PHY layer or a MAC layer based on the release information. The selection of the resource may be done by a MAC layer.

[66] The transmitter 1302 may, in operation, transmit the subsequent transmission using the selected resource. The transmitter 1302 may be further configured to transmit the release information to one or more other communication apparatus different from the another communication apparatus.

[67] For example, the communication apparatus 1300 may be a UE, and the circuitry 1314 may, in operation, determine release information relating to a reserved resource, the reserved resource being reserved for a transmission from

the communication apparatus. The transmitter 1302 may, in operation, transmit the release information to another communication apparatus.

[68] The receiver 1304 may, in operation, receive the release information from a base station, an access point (AP) or a communication apparatus different from the another communication apparatus. The release information may be received over a PSFCH. The circuitry 1314 may be further configured to select a resource from a plurality of resource candidates when the communication apparatus is to do a subsequent transmission, wherein the plurality of resource candidates includes the reserved resource, and wherein the transmitter 1302 may be further configured to transmit the subsequent transmission using the selected resource.

[69] The circuitry 1314 may be further configured to exclude or not exclude the reserved resource from the plurality of resource candidates, wherein judgement for excluding or not excluding the reserved resource from the plurality of resource candidates may be done by a PHY layer or a MAC layer based on the release information. The selection of the resource may be done by a MAC layer. The transmitter 1302 may be further configured to transmit the release information to a group of communication apparatuses.

[70] As described above, the embodiments of the present disclosure provide an advanced communication system, communication methods and communication apparatuses for utilization of released resource that advantageously reduces chances of over-the-air collisions on the released resource.

[71] The present disclosure can be realized by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be partly or entirely realized by an LSI such as an integrated circuit, and each process described in the each embodiment may be controlled partly or entirely by the same LSI or a combination of LSIs. The LSI may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. The LSI may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit, a

general-purpose processor, or a special-purpose processor. In addition, a FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuit cells disposed inside the LSI can be reconfigured may be used. The present disclosure can be realized as digital processing or analogue processing. If future integrated circuit technology replaces LSIs as a result of the advancement of semiconductor technology or other derivative technology, the functional blocks could be integrated using the future integrated circuit technology. Biotechnology can also be applied.

[72] The present disclosure can be realized by any kind of apparatus, device or system having a function of communication, which is referred as a communication apparatus.

[73] Some non-limiting examples of such communication apparatus include a phone (e.g, cellular (cell) phone, smart phone), a tablet, a personal computer (PC) (e.g, laptop, desktop, netbook), a camera (e.g, digital still/video camera), a digital player (digital audio/video player), a wearable device (e.g, wearable camera, smart watch, tracking device), a game console, a digital book reader, a telehealth/telemedicine (remote health and medicine) device, and a vehicle providing communication functionality (e.g., automotive, airplane, ship), and various combinations thereof.

[74] The communication apparatus is not limited to be portable or movable, and may also include any kind of apparatus, device or system being non-portable or stationary, such as a smart home device (e.g, an appliance, lighting, smart meter, control panel), a vending machine, and any other “things” in a network of an “Internet of Things (IoT)”.

[75] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[76] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication device performing a function of communication described in the present disclosure. For example, the communication apparatus may comprise a controller or a sensor that generates

control signals or data signals which are used by a communication device performing a communication function of the communication apparatus.

[77] The communication apparatus also may include an infrastructure facility, such as a base station, an access point, and any other apparatus, device or system that communicates with or controls apparatuses such as those in the above non-limiting examples.

[78] It will be understood that while some properties of the various embodiments have been described with reference to a device, corresponding properties also apply to the methods of various embodiments, and vice versa.

[79] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present disclosure as shown in the specific embodiments without departing from the spirit or scope of the disclosure as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

CLAIMS

1. A communication apparatus comprising:

a receiver which, in operation, receives release information relating to a reserved resource from another communication apparatus, the reserved resource being reserved for a transmission from the another communication apparatus; and

circuitry which, in operation, selects a resource from a plurality of resource candidates when the communication apparatus is to do a subsequent transmission, wherein the plurality of resource candidates includes the reserved resource.

2. The communication apparatus according to claim 1, wherein the release information is received over a Physical Sidelink Feedback Channel (PSFCH).

3. The communication apparatus according to claim 1, wherein the circuitry is further configured to exclude or not exclude the reserved resource from the plurality of resource candidates, wherein judgement for excluding or not excluding the reserved resource from the plurality of resource candidates is done by a PHY layer or a MAC layer based on the release information.

4. The communication apparatus according to claim 1, wherein the selection of the resource is done by a MAC layer.

5. The communication apparatus according to claim 1, further comprising a transmitter, which, in operation, transmits the subsequent transmission using the selected resource.

6. The communication apparatus according to claim 5, wherein the transmitter is further configured to transmit the release information to one or more other communication apparatus different from the another communication apparatus.

7. A communication apparatus comprising:

circuitry which, in operation, determines release information relating to a reserved resource, the reserved resource being reserved for a transmission from the communication apparatus; and

a transmitter which, in operation, transmits the release information to another communication apparatus.

8. The communication apparatus according to claim 7, further comprising a receiver, which, in operation, receives the release information from a base station, an access point (AP) or a communication apparatus different from the another communication apparatus.

9. The communication apparatus according to claim 8, wherein the release information is received over a PSFCH.

10. The communication apparatus according to claim 7, wherein the circuitry is further configured to select a resource from a plurality of resource candidates when the communication apparatus is to do a subsequent transmission, wherein the plurality of resource candidates includes the reserved resource, and wherein the transmitter is further configured to transmit the subsequent transmission using the selected resource.

11. The communication apparatus according to claim 10, wherein the circuitry is further configured to exclude or not exclude the reserved resource from the plurality of resource candidates, wherein judgement for excluding or not excluding the reserved resource from the plurality of resource candidates is done by a PHY layer or a MAC layer based on the release information.

12. The communication apparatus according to claim 10, wherein the selection of the resource is done by a MAC layer.

13. The communication apparatus according to claim 7, wherein the transmitter is further configured to transmit the release information to a group of communication apparatuses.

14. A communication method comprising:

receiving release information relating to a reserved resource, the reserved resource being reserved for a transmission from a communication apparatus; and

selecting a resource from a plurality of resource candidates when a subsequent transmission is to be done, wherein the plurality of resource candidates includes the reserved resource.

15. A communication method comprising:

determining release information relating to a reserved resource, the reserved resource being reserved for a transmission; and

transmitting the release information to a communication apparatus.