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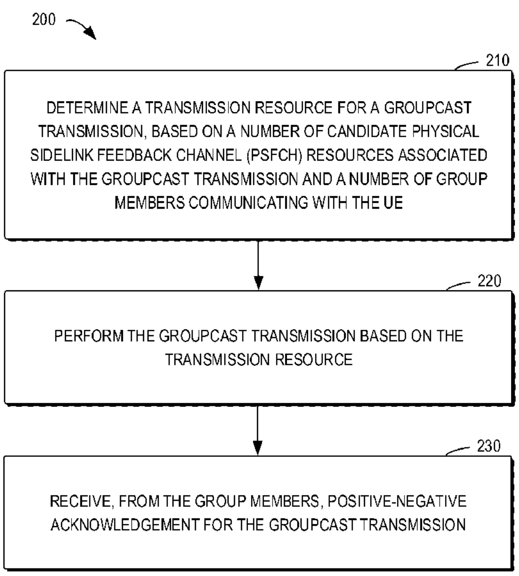

FIG. 2

(57) Abstract: Embodiments of the present disclosure relate to physical sidelink feedback channel (PSFCH) transmissions on an unlicensed spectrum. In some embodiments, a user equipment (UE) determines a transmission resource for a groupcast transmission, based on a number of candidate PSFCH resources associated with the groupcast transmission and a number of group members communicating with the UE. Then, the UE performs the groupcast transmission based on the transmission resource. Moreover, the UE receives, from the group members, positive-negative acknowledgement for the groupcast transmission. In this way, it is possible to improve the capacity of the PSFCH resources, and thus improve sidelink transmission efficiency.

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PSFCH TRANSMISSIONS ON AN UNLICENSED SPECTRUM

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to physical sidelink feedback channel (PSFCH) transmissions on an unlicensed spectrum.

BACKGROUND

[0002] A wireless communications system may include one or multiple network communication devices, such as base stations, which may be otherwise known as an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. Each network communication devices, such as a base station may support wireless communications for one or multiple user communication devices, which may be otherwise known as user equipment (UE), or other suitable terminology. The wireless communications system may support wireless communications with one or multiple user communication devices by utilizing resources of the wireless communication system (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers). Additionally, the wireless communications system may support wireless communications across various radio access technologies including third generation (3G) radio access technology, fourth generation (4G) radio access technology, fifth generation (5G) radio access technology, among other suitable radio access technologies beyond 5G (e.g., sixth generation (6G)).

[0003] With the development of communication technologies, several technologies have been proposed. In the third generation partnership project (3GPP) release 16 (Rel-16), hybrid automatic repeat request (HARQ) feedback on a PSFCH was introduced to achieve sidelink unicast and groupcast communications. In 3GPP release 18 (Rel-18), HARQ feedback for the sidelink transmission on an unlicensed spectrum is a suitable way to achieve the high reliability of sidelink communications. However, enhancements on the PSFCH transmissions on the unlicensed spectrum are still needed.

SUMMARY

[0004] The present disclosure relates to apparatuses, methods, and systems that support PSFCH transmissions on an unlicensed spectrum. With the apparatuses and methods, it is possible to improve the capacity of the PSFCH resources and thus improve sidelink communication efficiency.

[0005] In a first aspect, there is provided a terminal device (UE). The UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: determine a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE; perform the groupcast transmission based on the transmission resource; and receive, from the group members, positive-negative acknowledgement for the groupcast transmission.

[0006] In a second aspect, there is provided a method performed by the UE. The method comprises: determining a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE; performing the groupcast transmission based on the transmission resource; and receiving, from the group members, positive-negative acknowledgement for the groupcast transmission.

[0007] In a third aspect, there is provided a processor for wireless communication. The at least one processor comprises at least one controller coupled with at least one memory and configured to cause the at least one processor to: determine a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE; perform the groupcast transmission based on the transmission resource; and receive, from the group members, positive-negative acknowledgement for the groupcast transmission.

[0008] In some implementations of the method and the UE described herein, determining the transmission resource comprises: selecting, from one or more candidate resource pools configured with candidate PSFCH resources, a resource pool configured with a PSFCH occupying a dedicated interlace, based on determining that the number of candidate PSFCH resources of the resource pool is greater than or equal to the number of group members.

[0009] In some implementations of the method and the UE described herein, determining the transmission resource comprises: determining a frequency domain resource for the groupcast transmission as a plurality of subchannels, the number of candidate PSFCH resources associated with the plurality of subchannels being greater than or equal to the number of group members.

[0010] In some implementations of the method and the UE described herein, a period of the candidate PSFCH resources comprises a first plurality of slots, and determining the transmission resource comprises: determining a time domain resource for the groupcast transmission as a second plurality of slots, the candidate PSFCH resources associated with the second plurality of slots being in a same PSFCH transmission occasion. In some implementations of the method and the UE described herein, the groupcast transmission in the second plurality of slots occupies a same subchannel in a frequency domain. In some implementations of the method and the UE described herein, the candidate PSFCH resources associated with the second plurality of slots are used by the group members in the PSFCH transmission occasion. In some implementations of the method and the UE described herein, a number of the first plurality of slots is the same as a number of the second plurality of slots.

[0011] Some implementations of the method and apparatuses described herein may further include applying an orthogonal cover code (OCC) sequence within the dedicated interlace. In some implementations of the method and the UE described herein, the OCC sequence is applied to a plurality of consecutive resource blocks (RBs) within the dedicated interlace. In some implementations of the method and the UE described herein, the OCC sequence is not applied to remaining one or more RBs if a number of the remaining one or more RBs is smaller than a length of the OCC sequence, the remaining one or more RBs being determined by excluding the plurality of consecutive RBs from the dedicated interlace. In some implementations of the method and the UE described herein, receiving the positive-negative acknowledgement comprises: performing no detection for the positive-negative acknowledgement on the remaining one or more RBs. Some implementations of the method and apparatuses described herein may further include transmitting, to the group members in sidelink control information (SCI), an indication indicating at least one of the following: a length of the OCC sequence; or whether to apply the OCC sequence.

[0012] Some implementations of the method and apparatuses described herein may further include mapping a long sequence for the PSFCH to a first plurality of RBs within the dedicated interlace, the long sequence occupying a second plurality of RBs. In some implementations of the method and the UE described herein, receiving positive-negative acknowledgement comprises: performing no detection for the positive-negative acknowledgement on remaining one or more RBs if a number of the remaining one or more

RBs is smaller than a number of the second plurality of RBs, the remaining one or more RBs being determined by excluding the first plurality of RBs from the dedicated interlace. In some implementations of the method and the UE described herein, a number of the second plurality of RBs is pre-defined or indicated in an SCI. In some implementations of the method and the UE described herein, a number of the second plurality of RBs is configured per resource pool.

[0013] It is to be understood that the summary section is not intended to identify key or essential features of embodiments of the present disclosure, nor is it intended to be used to limit the scope of the present disclosure. Other features of the present disclosure will become easily comprehensible through the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 illustrates an example of a wireless communications system that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure;

[0015] FIG. 2 illustrates a flowchart of a method that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure;

[0016] FIG. 3 illustrates an example resource pool configuration in accordance with aspects of the present disclosure;

[0017] FIG. 4 illustrates an example resource pool configuration in accordance with aspects of the present disclosure;

[0018] FIGS. 5A and 5B illustrate an example use of RB level OCC for RBs within the interlace with occ-length=2 and occ-length=4 in accordance with aspects of the present disclosure respectively;

[0019] FIGS. 6A and 6B illustrate example phase rotations with sequence length=12 and sequence length=24 in accordance with aspects of the present disclosure respectively;

[0020] FIG. 7 illustrates an example of a device that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure; and

[0021] FIG. 8 illustrates an example of a processor that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure.

[0022] Throughout the drawings, the same or similar reference numerals represent the same or similar elements.

DETAILED DESCRIPTION

[0023] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below.

[0024] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0025] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) 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 do not necessarily refer to the same embodiment(s). 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.

[0026] It shall be understood that although the terms “first” and “second” or the like 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 element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as “best,” “lowest,” “highest,” “minimum,” “maximum,” or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, higher, or otherwise preferable to other selections.

[0027] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of 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, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof. For example, the term "includes" and its variants are to be read as open terms that mean "includes, but is not limited to." The term "based on" is to be read as "based at least in part on." The term "one embodiment" and "an embodiment" are to be read as "at least one embodiment." The term "another embodiment" is to be read as "at least one other embodiment." The use of an expression such as "A and/or B" can mean either "only A" or "only B" or "both A and B." Other definitions, explicit and implicit, may be included below.

[0028] As mentioned above, in Rel-18, HARQ feedback for sidelink transmission on an unlicensed spectrum is a suitable way to achieve the high reliability of sidelink communications. The support of sidelink on an unlicensed spectrum has been discussed as follows.

1. Study and specify support of sidelink on an unlicensed spectrum for both mode 1 and mode 2 where Uu operation for mode 1 is limited to licensed spectrum only [RAN1, RAN2, RAN4]
    - Channel access mechanisms from NR-U shall be reused for sidelink unlicensed operation
        - Assess the applicability of sidelink resource reservation from Rel-16/Rel-17 to sidelink unlicensed operation within the boundaries of unlicensed channel access mechanism and operation
            - No specific enhancements for Rel-17 resource allocation mechanisms
            - If the existing NR-U channel access framework does not support the required SL-U functionality, WGs will make appropriate recommendations for RAN approval.
    - Physical channel design framework: Required changes to NR sidelink physical channel structures and procedures to operate on an unlicensed spectrum
        - The existing NR sidelink and NR-U channel structure shall be reused as the baseline.
    - No specific enhancements for existing NR SL feature

- The study should focus on FR1 unlicensed bands (n46 and n96/n102) and is to be completed by RAN#98.

[0029] The structure of legacy PSFCH and resource mapping have been specified, for example, in the technical specification (TS) 38.213 as follows:

16.3 UE procedure for reporting HARQ-ACK on sidelink

A UE can be indicated by an SCI format scheduling a PSSCH reception to transmit a PSFCH with HARQ-ACK information in response to the PSSCH reception. The UE provides HARQ-ACK information that includes ACK or NACK, or only NACK.

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

A UE expects that a slot t'^{SL}_{k} $(0 \le k < T'_{max})$ has a PSFCH transmission occasion resource if k mod $N^{\mathrm{PSFCH}}_{\mathrm{PSSCH}} = 0$, where t'^{SL}_{k} is defined in [6, TS 38.214], and T'_{max} is a number of slots that belong to the resource pool within 10240 msec according to [6, TS 38.214], and $N^{\mathrm{PSFCH}}_{\mathrm{PSSCH}}$ is provided by *sl-PSFCH-Period*.

A UE may be indicated by higher layers to not transmit a PSFCH in response to a PSSCH reception [11, TS 38.321].

If a UE receives a PSSCH in a resource pool and the HARQ feedback enabled/disabled indicator field in an associated SCI format 2-A or a SCI format 2-B has value 1 [5, TS 38.212], the UE provides the HARQ-ACK information in a PSFCH transmission in the resource pool. The UE transmits the PSFCH in a first slot that includes PSFCH resources and is at least a number of slots, provided by *sl-MinTimeGapPSFCH*, of the resource pool after a last slot of the PSSCH reception.

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

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

A UE determines a number of PSFCH resources available for multiplexing HARQ-

ACK information in a PSFCH transmission as $R_{\text{PRB, CS}}^{\text{PSFCH}} = N_{\text{type}}^{\text{PSFCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}} \cdot N_{\text{CS}}^{\text{PSFCH}}$ where $N_{\text{CS}}^{\text{PSFCH}}$ is a number of cyclic shift pairs for the resource pool provided by *sl-NumMuxCS-Pair* and, based on an indication by *sl-PSFCH-CandidateResourceType*,

- if *sl-PSFCH-CandidateResourceType* is configured as *startSubCH*, $N_{\text{type}}^{\text{PSFCH}} = 1$ and the $M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs are associated with the starting sub-channel of the corresponding PSSCH;
- if *sl-PSFCH-CandidateResourceType* is configured as *allocSubCH*, $N_{\text{type}}^{\text{PSFCH}} = N_{\text{subch}}^{\text{PSSCH}}$ and the $N_{\text{subch}}^{\text{PSSCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs are associated with the $N_{\text{subch}}^{\text{PSSCH}}$ sub-channels of the corresponding PSSCH.

The PSFCH resources are first indexed according to an ascending order of the PRB index, from the $N_{\text{type}}^{\text{PSFCH}} \cdot M_{\text{subch, slot}}^{\text{PSFCH}}$ PRBs, and then according to an ascending order of the cyclic shift pair index from the $N_{\text{CS}}^{\text{PSFCH}}$ cyclic shift pairs.

A UE determines an index of a PSFCH resource for a PSFCH transmission in response to a PSSCH reception as $(P_{\text{ID}} + M_{\text{ID}}) mod R_{\text{PRB, CS}}^{\text{PSFCH}}$ where P_{ID} is a physical layer source ID provided by SCI format 2-A or 2-B [5, TS 38.212] scheduling the PSSCH reception, and M_{ID} is the identity of the UE receiving the PSSCH as indicated by higher layers if the UE detects a SCI format 2-A with Cast type indicator field value of "01"; otherwise, M_{ID} is zero.

A UE determines a m_0 value, for computing a value of cyclic shift α [4, TS 38.211], from a cyclic shift pair index corresponding to a PSFCH resource index and from $N_{\text{CS}}^{\text{PSFCH}}$ using Table 16.3-1.

Table 16.3-1: Set of cyclic shift pairs

$N_{\text{CS}}^{\text{PSFCH}}$	m_0					
	Cyclic Shift Pair Index 0	Cyclic Shift Pair Index 1	Cyclic Shift Pair Index 2	Cyclic Shift Pair Index 3	Cyclic Shift Pair Index 4	Cyclic Shift Pair Index 5
1	0	-	-	-	-	-
2	0	3	-	-	-	-
3	0	2	4	-	-	-
6	0	1	2	3	4	5

A UE determines a m_{cs} value, for computing a value of cyclic shift α [4, TS 38.211], as in Table 16.3-2 if the UE detects a SCI format 2-A with Cast type indicator field value of "01" or "10", or as in Table 16.3-3 if the UE detects a SCI format 2-B or a SCI format 2-A with Cast type indicator field value of "11". The UE applies one cyclic shift from a cyclic shift pair to a sequence used for the PSFCH transmission [4, TS 38.211].

Table 16.3-2: Mapping of HARQ-ACK information bit values to a cyclic shift, from a cyclic shift pair, of a sequence for a PSFCH transmission when HARQ-ACK information includes ACK or NACK

HARQ-ACK Value	0 (NACK)	1 (ACK)
Sequence cyclic shift	0	6

Table 16.3-3: Mapping of HARQ-ACK information bit values to a cyclic shift, from a cyclic shift pair, of a sequence for a PSFCH transmission when HARQ-ACK information includes only NACK

HARQ-ACK Value	0 (NACK)	1 (ACK)
Sequence cyclic shift	0	N/A

[0030] As described above, HARQ feedback may be classified as two options, also referred to as HARQ feedback option 1 and HARQ feedback option 2. With HARQ feedback option 1, only non-acknowledgement (NACK) is fed back to the transmit UE. With HARQ feedback option 2, acknowledgement (ACK) or NACK is fed back to the transmit UE. Inventors have noticed that for the groupcast transmission in sidelink on the unlicensed spectrum (SL-U), HARQ feedback option 1 is not applicable since the transmit UE cannot distinguish the discontinuous transmission (DTX) status and listen-before-talk (LBT) failure if the transmit UE doesn’t receive any NACK. So to achieve higher reliability of sidelink groupcast, HARQ feedback option 2 should be considered.

[0031] In addition, the resource pool selection has been specified, for example, in TS 38.321, as follows.

If the MAC entity has been configured with Sidelink resource allocation mode 2 to transmit using pool(s) of resources in a carrier as indicated in TS 38.331 [5] or TS 36.331 [21] based on sensing or random selection, the MAC entity shall for each Sidelink process:

NOTE 1: If the MAC entity is configured with Sidelink resource allocation mode 2 to transmit using a pool of resources in a carrier as indicated in TS 38.331 [5] or TS 36.331 [21], the MAC entity can create a selected sidelink grant on the pool of resources based on random selection or sensing only after releasing configured sidelink grant(s), if any.

NOTE 2: The MAC entity expects that PSFCH is always configured by RRC for at least one pool of resources in *sl-TxPoolSelectedNormal* and for the resource pool in *sl-TxPoolExceptional* in case that at least a logical channel configured with *sl-HARQ-FeedbackEnabled* is set to *enabled*.

1> if the MAC entity has selected to create a selected sidelink grant corresponding to transmissions of multiple MAC PDUs, and SL data is available in a logical channel:

2> if the MAC entity has not selected a pool of resources allowed for the logical channel:

3> if *sl-HARQ-FeedbackEnabled* is set to *enabled* for the logical channel:

4> select any pool of resources configured with PSFCH resources among the pools of resources;

3> else:

4> select any pool of resources among the pools of resources;

5> if HARQ feedback is enabled for groupcast:

6> if both a group size and a member ID are provided by upper layers and the group size is not greater than the number of candidate PSFCH resources associated with this sidelink grant:

7> select either positive-negative acknowledgement or negative-only acknowledgement.

NOTE 4: Selection of positive-negative acknowledgement or negative-only acknowledgement is up to UE implementation.

6> else:

7> select negative-only acknowledgement.

[0032] In the last 3GPP RAN#1 meeting, two alternatives on the structure of the PSFCH for sidelink on the unlicensed spectrum (SL-U) were agreed as follows.

Agreement
Regarding PSFCH transmission with 15 kHz and 30 kHz SCS:

- One of the following alternatives is (pre-)configured:
    - Alt 1-1b: each PSFCH transmission occupies 1 common interlace and K3 dedicated PRB(s)
        - K3 is (pre-)configured
            - Value range for K3 at least includes {1, 2, 5}
        - K3 dedicated PRB(s) are on the same interlace
        - There can be some guardband PRB(s) between common PRB and dedicated PRB
            - FFS details, e.g., whether/how to derive the number of guardband PRB(s), whether to additionally introduce a

(pre-)configured gap (including 0), or whether this can be satisfied by (pre-)configuration and there is no additional specification impact (e.g., setting proper bit values in bitmap for PSFCH PRB allocation), etc.

- FFS whether to additionally introduce guardband RE between common PRB and dedicated PRB

- On the K3 dedicated PRB(s), multiple CS pairs can be used as in legacy NR SL PSFCH transmission
- When a PRB of common interlace and a dedicated PRB locate within the same 1 MHz bandwidth, UE only transmits on the dedicated PRB subject to meeting OCB requirements
- FFS: whether to reduce power on common PRBs

- Alt 2-3a: each PSFCH transmission occupies 1 dedicated interlace

- PSSCH transmissions on non-overlapped resources are mapped to orthogonal dedicated PRBs for PSFCH transmission
- FFS: whether or not to support PRB-level cyclic shift hopping as in NR-U to reduce PAPR
- FFS: whether to drop common PRBs if the dedicated PRBs can already satisfy OCB requirement

[0033] As agreed above, in SL-U, to meet the occupied channel bandwidth (OCB) requirement, two PSFCH structures have been agreed to be (pre-)configured. For example, for 20MHz bandwidth in one RB set, there are 100 PRBs for 15kHz subcarrier spacing (SCS), and 50 PRBs for 30kHz SCS. The capacity comparison between Rel-16 sidelink and the PSFCH structure Alt 2-3a where each PSFCH transmission occupies 1 dedicated interlace is shown in Table 1.

Table 1: capacity comparison

N_{CS}^{PSFCH}	SCS	Maximum number of PSFCH resources of R16 sidelink	Maximum number of PSFCH resources of Alt 2-3a
1	15kHz	100	10
	30kHz	50	5
2	15kHz	200	20
	30kHz	100	10
3	15kHz	300	30
	30kHz	150	15
6	15kHz	600	60

	30kHz	300	30

[0034] For the PSFCH structure Alt 2-3a, the inventors have noticed that the capacity of the PSFCH resources is limited, especially when HARQ feedback option 2 (i.e. with positive-negative acknowledgement) is applied in the sidelink groupcast transmission. For example, if an SCS of a bandwidth part (BWP) is configured as 30kHz, there are 5 interlaces within one RB set. If the groupcast with HARQ feedback option 2 is transmitted on a sub-channel, the number of available PSFCH resources is only 6 when the number of cyclic shift pairs is configured to 6. In this case, the PSFCH structure Alt 2-3a cannot support groupcast with HARQ feedback option 2 well.

[0035] In view of the above, as of now, there is no effective way to support PSFCH transmissions on the unlicensed spectrum, especially, in terms of the capacity of PSFCH resources for a groupcast transmission with HARQ feedback option 2. Therefore, there is a need for an improved solution for the PSFCH transmissions on the unlicensed spectrum. Especially, there is a need to enhance the capacity of PSFCH resources for the groupcast transmission.

[0036] Embodiments of the present disclosure provide a solution for PSFCH transmissions on the unlicensed spectrum. In one aspect of the solution of the present disclosure, a UE determines a transmission resource for a groupcast transmission, based on a number of candidate PSFCH resources associated with the groupcast transmission and a number of group members communicating with the UE. Then, the UE performs the groupcast transmission based on the transmission resource. Moreover, the UE receives, from the group members, positive-negative acknowledgement for the groupcast transmission.

[0037] By determining the transmission resource based on the number of candidate PSFCH resources and the number of group members, this solution allows ensuring that there are sufficient PSFCH resources for transmitting the HARQ feedback for the groupcast transmission. In this way, it is possible to improve the capacity of the PSFCH resources, and thus improve sidelink transmission efficiency.

[0038] The term “positive-negative acknowledgement” refer to HARQ feedback that includes ACK or NACK, when HARQ feedback option 2 is applied. As used herein, the “positive acknowledgement” may be used with the same meaning as “ACK”, and the “negative acknowledgement” may be used with the same meaning as “NACK”.

[0039] Principles and implementations of embodiments of the present disclosure will be described in detail below with reference to the figures.

[0040] FIG. 1 illustrates an example of a wireless communications system 100 that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a long term evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as a new radio (NR) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0041] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0042] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, messaging, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0043] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0044] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the core network 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0045] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink (SL). For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0046] A network entity 102 may support communications with the core network 106, or with another network entity 102, or both. For example, a network entity 102 may interface with the core network 106 through one or more backhaul links 116 (e.g., via an S1, N2, N2, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the core network 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0047] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0048] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0049] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0050] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0051] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul communication link (e.g., F1, F1 c, F1 u), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links .

[0052] The core network 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The core network 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the core network 106.

[0053] The core network 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the core network 106 via a network entity 102. The core network 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the core network 106 (e.g., one or more network functions of the core network 106).

[0054] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0055] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., μ=0) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., μ=0) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., μ=1) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., μ=2) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., μ=3) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., μ=4) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0056] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0057] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., μ=0, μ=1, μ=2, μ=3, μ=4) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., μ=0) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0058] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz –

300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0059] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., μ=0), which includes 15 kHz subcarrier spacing; a second numerology (e.g., μ=1), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., μ=2), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., μ=3), which includes 120 kHz subcarrier spacing.

[0060] Reference is now made to FIG. 2, which illustrates a flowchart of a method 200 that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure. The operations of the method 200 may be implemented by a device or its components as described herein. For example, the operations of the method 200 may be performed by the UE 104 as described herein. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware. For the purpose of discussion, the method 200 will be described with reference to FIG. 1.

[0061] At 210, the method may include determining a transmission resource for a groupcast transmission, based on the number of candidate PSFCH resources associated with the groupcast transmission and the number of group members communicating with the UE. The number of group members may be associated with the group size which comprises the number of group members and the transmit UE (i.e. the UE 104). Hereinafter, "the number of group members" and "the group size" may be used interchangeably in some cases when performing the methods of the present disclosure. At 220, the method may include performing the groupcast transmission based on the transmission resource. After receiving the groupcast transmission, the group members may provide the HARQ feedback for the groupcast transmission. In some example embodiments to be discussed below, HARQ feedback option 2 (i.e., positive-negative acknowledgement) may be taken as an example approach of the HARQ feedback for the groupcast transmission. Then, at 230, the method may include receiving, from the group members, the positive-negative acknowledgement for the groupcast transmission.

[0062] As discussed above, at least one resource pool may be configured with PSFCH resources if at least a logic channel configured with sl-HARQ-FeedbackEnabled is set to enabled. During the resource pool selection procedure, if data in a logic channel with sl-HARQ-FeedbackEnabled set to enabled is to be transmitted, a MAC layer of the UE 104 may select a resource pool from the least one resource pool configured with PSFCH resources.

[0063] In some embodiments, in case that at least a logical channel is configured with sl-HARQ-FeedbackEnabled set to enabled, at least one resource pool may be configured with a PSFCH of structure Alt 2-3a where the PSFCH transmission occupies a dedicated interlace. During the resource pool selection procedure, if data will be transmitted via groupcast with positive-negative acknowledgement, the UE 104 may select, from one or more candidate resource pools configured with candidate PSFCH resources, a resource pool configured with a PSFCH occupying a dedicated interlace (i.e. a PSFCH of structure Alt 2-3a), based on a determination that the number of candidate PSFCH resources of the resource pool is greater than or equal to the number of group members. In other words, if the number of group members is not greater than the number of candidate PSFCH resources associated with the sidelink grant, the UE 104 may not select this resource pool. In the following discussions, PSFCH structure Alt 2-3a may be taken as an example structure for the groupcast transmission with positive-negative acknowledgement.

[0064] For example, for a resource pool configured with a PSFCH of structure Alt 2-3a when the SCS in configured as 30 kHz, and related parameters of this resource pool are {the number of cyclic shift (CS) pairs, $sl - NumMuxCS - Pair,\ = 6$, the period of the PSFCH, sl-PSFCH-Period, =1}, the number of candidate PSFCH resources associated with a sub-channel is 6. When the sidelink groupcast transmission with positive-negative acknowledgement occupies one subchannel, the resource pool of structure Alt 2-3a may be selected if the number of group members is not greater than 6. When the sidelink groupcast transmission with positive-negative acknowledgement occupies two subchannels, the resource pool of structure Alt 2-3a may be selected if the number of group members is not greater than 12.

[0065] In some implementations, the UE 104 may determine a frequency domain resource for the groupcast transmission with a consideration of the number of candidate PSFCH resources associated with the sidelink grant and the number of group members. The number of candidate PSFCH resources associated with the sidelink grant may depend on the number of subchannels occupied by the groupcast transmission. In the sidelink system, the number of subchannels may be determined by the MAC layer of the UE 104. To avoid the limited capability of the PSFCH resources with structure Alt 2-3a, the MAC layer of the UE 104 may determine the number of subchannels based on the number of candidate PSFCH resources associated with the sidelink grant and the number of group members. For example, the UE 104 may select the number of subchannels to ensure that the number of candidate PSFCH resources is not smaller than the group size. In other words, the frequency domain resource for the groupcast transmission may be determined as a plurality of subchannels, if it is ensured that the number of candidate PSFCH resources associated with the plurality of subchannels is greater than or equal to the number of group members.

[0066] An example will be discussed with reference to FIG. 3, which illustrates an example resource pool configuration in accordance with aspects of the present disclosure. As shown in FIG. 3, related parameters of this resource pool configured with PSFCH structure Alt 2-3a are { $sl - NumMuxCS - Pair = 6$, sl-PSFCH-Period=1} and the SCS of the BWP is 30 kHz. If a sidelink groupcast transmission occupies one subchannel, there may be 6 candidate PSFCH resources associated with this transmission. In this case, if the sidelink groupcast transmission occupies subchannel#0 in slot 0, the associated PSFCH resources may be in slot 2, and the associated PSFCH resources may occupy interlace#0 with m0=0,1,2,3,4,5. If a sidelink groupcast transmission occupies two subchannels, there are 12 candidate PSFCH resources associated with this transmission. In this case, if the sidelink groupcast transmission occupies subchannel#0 and subchannel#1 in slot 0, the associated PSFCH resources may be in slot 2, and the associated PSFCH resources may occupy interlace#0 with m0=0,1,2,3,4,5 and interlace#1 with m0=0,1,2,3,4,5. So, for a sidelink groupcast transmission with 8 number of group members, the UE 104 may select at least two subchannels to avoid the PSFCH resource collision between its group members.

[0067] In some implementations, a period of the candidate PSFCH resources may comprise a plurality of slots (also referred to a first plurality of slots, for example, 2 or 4 slots), and in this case, the UE 104 may determine a time domain resource for the groupcast transmission as a plurality of slots (also referred to as a second plurality of slots). The candidate PSFCH resources associated with the second plurality of slots may be in the same PSFCH transmission occasion, or in other words, the candidate PSFCH resources of the groupcast transmission occupying the second plurality of slots may be in the same PSFCH transmission occasion. The candidate PSFCH resources associated with the second plurality of slots may be used by the group members in the PSFCH transmission occasion. As an example, to avoid resource collisions between group members, the groupcast transmission occupying the second plurality of slots may occupy the same subchannel in a frequency domain, which will be discussed in detail with reference to FIG. 4. For example, the number of the first plurality of slots may be the same as the number of the second plurality of slots, and in this case, the groupcast transmission may occupy the same number of slots as the period of the PSFCH resources.

[0068] FIG. 4 illustrates another example resource pool configuration in accordance with aspects of the present disclosure. As shown in FIG. 4, the period of PSFCH resources is configured as 2 slots. PSFCH resources associated with the groupcast transmission in slot 0 and PSFCH resources associated with the groupcast transmission in slot 1 are in the same PSFCH transmission occasion which is in slot 3. In this case, the sidelink groupcast transmission with positive-negative acknowledgement may occupy transmission resources both in slot 0 and slot 1. It may not be allowed to perform the sidelink transmission only in slot 0 or slot 1. At the receiving sides of the groupcast transmission, the associated PSFCHs to be used may be determined based on both transmission resources occupied by the groupcast transmission in slot 0 and slot 1. For example, if the sidelink groupcast transmission occupies subchannel#0 in slot 0 and subchannel#0 in slot 1, the candidate PSFCH resources in slot 3 for this groupcast transmission may be 6 PSFCH resources, i.e., {interlace#0,m0=0},{interlace#0,m0=1},{interlace#0,m0=2},{interlace#0,m0=3},{interlace#0,m0=4},{interlace#0,m0=5}. Compared to the legacy scheme where the groupcast transmission occupies either subchannel 0 in slot 0 or subchannel 0 in slot 1, and thus the number of candidate PSFCH resources is 3, it is allowed to double the number of PSFCH resources for this groupcast transmission configuring the groupcast transmission with transmission resources in slot 0 and slot 1.

[0069] In some examples, in a situation where a group member misses the reception of an SCI in slot 0 or slot 1, it may fail to find out the correct candidate PSFCH resources when the subchannels occupied by the groupcast transmission in slot 0 and slot 1 are different. For example, if a sidelink transmission occupies subchannel#0 in slot 0 and subchannel#2 in slot 1 respectively, when a group member receives both SCIs in slot 0 and slot 1, it may realize that the candidate PSFCH resources in slot 3 are {interlace#0,m0=0},{interlace#0,m0=2},{interlace#0,m0=4},{interlace#2,m0=1},{interlace#2,m0=3},{interlace#2,m0=5}. However if another group member only receives an SCI in slot 0, it may only find out the candidate PSFCH resources of {interlace#0,m0=0},{interlace#0,m0=2},{interlace#0,m0=4}. In this case, if this group member only identifies the PSFCH resources from the realized candidate PSFCH resources, it may cause PSFCH resource collisions between group members. To address this issue, a restriction that the subchannels occupied by the groupcast transmission in the second plurality of slots for the groupcast transmission should be the same may be applied.

[0070] In some implementations, the UE 104 may apply an OCC sequence within the dedicated interlace. For PSFCH structure Alt 2-3a, a PSFCH may occupy 1 interlace, and one interlace may have 10 or 11 PRBs (also referred to as interlace RBs (IRBs)). In this case, to increase the capability of the PSFCH resources within one interlace, RB level OCC in the frequency domain may be applied. As an example, the length of the OCC sequence (also referred to as occ-length) may be 2 or 4. The OCC sequences $w_n(i)$ with the occ-length of 2 or 4 may be shown in the following tables.

Table 2: occ-length=2

n	$w_n(i)$
0	[+1 +1]
1	[+1 -1]

Table 3: occ-length=4

n	$w_n(i)$
0	[+1 +1 +1 +1]
1	[+1 -1 +1 +1]
2	[+1 +1 -1 -1]
3	[+1 -1 -1 +1]

[0071] The OCC sequence may be applied to a plurality of consecutive RBs within the dedicated interlace. If the number of RBs is not an integer multiple of the occ-length, there may be remaining one or more RBs, which are determined by excluding the plurality of consecutive RBs from the dedicated interlace. In other words, there may be remaining one or more RBs if the number of the remaining one or more RBs is smaller than the occ-length.

The OCC sequence may not be applied to the remaining one or more RBs. Accordingly, when performing the reception of the positive-negative acknowledgement, the UE 104 may perform no detection for the positive-negative acknowledgement on the remaining one or more RBs.

[0072] FIGS. 5A and 5B illustrate an example use of RB level OCC for RBs within the dedicated interlace with occ-length=2 and occ-length=4 respectively. The RB level OCC may be applied for 10 or 11 RBs within one interlace. For example. as shown in FIG. 5A, for the case with occ-length=2, if the interlace has 10 RBs, adjacent RBs within the interlace may apply an OCC sequence. However, if the interlace has 11 RBs, there is one remaining RB, e.g., IRB#10 as shown in FIG. 5A, and the OCC sequence may not be applied to this IRB. As another example, as shown in FIG. 5B, for the case with occ-length=4, there are two remaining RBs if the interlace has 10 RBs, and there are 3 remaining RBs if the interlace has 11 RBs. The OCC sequence may not be applied to these remaining RBs. Accordingly, at the receiving side of the PSFCH, i.e. the UE 104, it may not detect the remaining RBs since there may have interference among UEs without the OCC sequence applied.

[0073] On PSFCH resources indexing within the candidate PSFCH resources, as an example, the PSFCH resources may be indexed with the following order: frequency domain->cyclic shift->OCC. As another example, the PSFCH resources may be indexed with the following order: frequency domain->OCC->cyclic shift.

[0074] For example, whether to apply the OCC may depend on the number of group members and the number of candidate PSFCH resources. Since the group size may not be known to the group member, the UE 104 may indicate, to the group members, whether to apply the OCC sequence and/or the occ-length based on the group size and the number of candidate PSFCH resources. The indication may be carried by an SCI, for example, the 1st-stage SCI or the 2nd-stage SCI. As an example, two fields may be carried by the SCI, where 1 bit may be used to indicate whether to apply the OCC sequence and X bits may be used to indicate the occ-length. In this case, if only occ-length of 2 and 4 are supported, X may be 1. As another example, one field may be carried by the SCI to indicate whether to apply the OCC sequence and the occ-length. In this case, if only occ-length 2 and 4 are supported, 2 bits may be used to indicate such information, for example, where '00' represents no occ, '01' represents occ-length=2, and '10' represents occ-length=4. As a further example, the occ-length may be (pre-)configured or pre-defined, and if not, the OCC sequence may not be applied.

[0075] According to the legacy PSFCH structure with repetitions on multiple RBs within the dedicated interlace, for example, 12-length sequence may be mapped to all 10 or 11 RBs within the dedicated interlace. For the legacy 12-length sequence, the phase rotations are shown in FIG. 6A. Since the length of the legacy sequence is 12, there are only 12 phase rotations to ensure orthogonality. For the groupcast transmission with positive-negative acknowledgement, each group member may need two statuses to report Ack or NACK, so there is a maximum of 6 group members to be multiplexed in one same RB, as follows:

- $\{m_0 + m_{cs} = 0\ for\ ACK, m_0 + m_{cs} = 6\ for\ NACK\}$ for UE1,
- $\{m_0 + m_{cs} = 1\ for\ ACK, m_0 + m_{cs} = 7\ for\ NACK\}$ for UE2,
- $\{m_0 + m_{cs} = 2\ for\ ACK, m_0 + m_{cs} = 8\ for\ NACK\}$ for UE3,
- $\{m_0 + m_{cs} = 3\ for\ ACK, m_0 + m_{cs} = 9\ for\ NACK\}$ for UE4,
- $\{m_0 + m_{cs} = 4\ for\ ACK, m_0 + m_{cs} = 10\ for\ NACK\}$ for UE5,
- $\{m_0 + m_{cs} = 5\ for\ ACK, m_0 + m_{cs} = 11\ for\ NACK\}$ for UE6

[0076] To improve the capacity of PSFCH resources, in some implementations, the UE 104 may increase the length of the sequence, and then map a long sequence for the PSFCH to a plurality of RBs (also referred to as a first plurality of RBs) within the dedicated interlace. In this manner, the long sequence may provide more statuses/phase rotations. The long sequence may occupy a plurality of RBs (also referred to as a second plurality of RBs). As an example, the number of the second plurality of RBs may be pre-defined in the specification. As another example, the number of the second plurality of RBs may be indicated in an SCI. In this case, the UE 104 may determine the number of the second plurality of RBs considering the capacity of PSFCH resources and also the interference to make a tradeoff. The number of the second plurality of RBs may be configured per resource pool.

[0077] As an example, if the length of the sequence is extended to 24, there may be 24 phase rotations. FIG. 6B illustrates example phase rotations with sequence length=24 in accordance with aspects of the present disclosure. In this case, the long sequence may occupy 2 RBs. For groupcast HARQ feedback option 2, each group member may need two statuses to report Ack or NACK, so there is a maximum of 12 group members that may be multiplexed.

[0078] During the long sequence mapping procedure, if the number of RBs within the dedicated interlace is not an integer multiple of the number of the second plurality of RBs occupied by the long sequence, there may be remaining one or more RBs, which are determined by excluding, from the dedicated interlace, the first plurality of RBs to which the long sequence has been mapped. In other words, there may be remaining one or more RBs if the number of the remaining one or more RBs is smaller than the number of the second plurality of RBs. In this case, on the remaining one or more RBs, it may be up to UE implementation to determine what is transmitted. When performing the reception of the positive-negative acknowledgement, the UE 104 may perform no detection for the positive-negative acknowledgement on the remaining one or more RBs.

[0079] As an example, the long sequence may occupy M RBs, where M is not larger than the number of RBs within the dedicated interlace (e.g., 10 or 11 RBs.). The TS 38.211 with long sequence extension may be modified as follows:

8.3.4.2 PSFCH format 0

8.3.4.2.1 Sequence generation

The sequence $x(n)$ shall be generated according to

$$x(n) = r_{u,v}^{\alpha,\delta}(n)$$

$$n = 0,1,\dots,M * N_{\mathrm{sc}}^{\mathrm{RB}} - 1$$

where $r_{u,v}^{(\alpha,\delta)}(n)$ is given by clause 6.3.2.2 with the following exceptions:

- m_{cs} is given by clause 16.3 of [5, TS 38.213];
- m_0 is given by clause 16.3 of [5, TS 38.213];
- $l = 0$;
- l' is the index of the OFDM symbol in the slot that corresponds to the second OFDM symbol of the PSFCH transmission in the slot given by [5, TS 38.213];
- $u = n_{\mathrm{ID}} \bmod 30$ and $v = 0$ with n_{ID} given by the higher-layer parameter *sl-PSFCH-HopID* if configured; otherwise, $u = 0$.
- $c_{\mathrm{init}} = n_{\mathrm{ID}}$ with n_{ID} given by the higher-layer parameter *sl-PSFCH-HopID* if configured; otherwise, $c_{\mathrm{init}} = 0$.

6.3.2.2.2 Cyclic shift hopping

The cyclic shift α varies as a function of the symbol and slot number according to

$$\alpha_l = \frac{2\pi}{M * N_{\mathrm{sc}}^{\mathrm{RB}}}\left(\left(m_0 + m_{\mathrm{cs}} + m_{\mathrm{int}} + n_{\mathrm{cs}}\left(n_{\mathrm{s,f}}^{\mu}, l + l'\right)\right) \bmod \mathrm{M}* N_{\mathrm{sc}}^{\mathrm{RB}}\right)$$

where

- $n_{s,f}^{\mu}$ is the slot number in the radio frame
- l is the OFDM symbol number in the PUCCH transmission where $l = 0$ corresponds to the first OFDM symbol of the PUCCH transmission,
- l' is the index of the OFDM symbol in the slot that corresponds to the first OFDM symbol of the PUCCH transmission in the slot given by [5, TS 38.213]
- m_0 is given by [5, TS 38.213] for PUCCH format 0 and 1 while for PUCCH format 3 and 4 is defined in clause 6.4.1.3.3.1
- $m_{cs} = 0$ except for PUCCH format 0 when it depends on the information to be transmitted according to clause 9.2 of [5, TS 38.213].
- m_{int} is given by
  - $m_{int} = 5floor(n_{IRB}^{\mu}/2)$ for PUCCH formats 0 and 1 if PUCCH shall use interlaced mapping according to any of the higher-layer parameters *useInterlacePUCCH-PUSCH* in *BWP-UplinkCommon* or *useInterlacePUCCH-PUSCH* in *BWP-UplinkDedicated*, where n_{IRB}^{μ} is the resource block number within the interlace;
  - $m_{int} = 0$ otherwise

The function $n_{cs}(n_c, l)$ is given by

$$n_{cs}(n_{s,f}^{\mu}, l) = \sum_{m=0}^{7} 2^m\, c(8N_{symb}^{slot} n_{s,f}^{\mu} + 8l + m)$$

where the pseudo-random sequence $c(i)$ is defined by clause 5.2.1. The pseudo-random sequence generator shall be initialized with $c_{init} = n_{ID}$, where n_{ID} is given by the higher-layer parameter *hoppingId* if configured, otherwise $n_{ID} = N_{ID}^{cell}$.

[0080] As an example, if the cyclic shift hopping is supported, the long sequence mapping to M RBs may be repeated within the interlace floor (the number of RBs within interlace/M). As another example, if the cyclic shift hopping is supported, the hopping may be done as m_{int}.

[0081] In some other embodiments, the at least one resource pool may be configured with a PSFCH of structure Alt 1-1b where the PSFCH transmission occupies a common interlace and K3 dedicated PRB(s). During the resource pool selection procedure, if data will be transmitted via groupcast with positive-negative acknowledgement, the UE 104 may select, from one or more candidate resource pools configured with candidate PSFCH resources, a resource pool configured with a PSFCH occupying a common interlace and K3 dedicated PRB(s) (i.e., with structure Alt 1-1b). In this case, resource pools configured with a PSFCH of structure Alt 2-3a (where the PSFCH transmission occupies a dedicated interlace) may not be allowed for the groupcast transmission with positive-negative acknowledgement. Based on such resource pool configuration with PSFCH structure Alt 1-1b and resource pool selection, there is no capacity issue of PSFCH resources for the groupcast transmission.

[0082] In some further embodiments, the at least one resource pool may be configured with a PSFCH of structure Alt 1-1b or a PSFCH of structure Alt 2-3a. In this case, during the resource pool selection procedure, if data will be transmitted via groupcast with positive-negative acknowledgement, the UE 104 may select, from one or more candidate resource pools configured with candidate PSFCH resources, a resource pool configured with a PSFCH of structure Alt 1-1b. Alternatively or additionally, whether a resource pool configured with a PSFCH of structure Alt 2-3a may be selected is determined based on the number of group members and the number of candidate PSFCH resources associated with the sidelink grant. The UE 104 may select the resource pool with a PSFCH of structure Alt 2-3a if it determines that the number of candidate PSFCH resources associated with the sidelink grant is greater than or equal to the number of group members.

[0083] It is to be understood that such resource pool configuration with PSFCH structure Alt 1-1b and the related resource pool selection method may not rely on any other steps in FIGS.2 to 6B. In other words, the resource pool configuration with PSFCH structure Alt 1-1b and the related resource pool selection method may be embodied in independent embodiments. For example, the UE 104 may only select the resource pool with PSFCH structure Alt 1-1b to avoid capacity limitation issues.

[0084] According to some embodiments with reference to FIGS.2 to 6B, it is allowed to ensure sufficient PSFCH resources for transmitting the HARQ feedback for the groupcast transmission. In this way, it is possible to improve the capacity of the PSFCH resources, and thus improve sidelink transmission efficiency.

[0085] FIG. 7 illustrates an example of a device 700 that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure. The device 700 may be an example of the UE 104 as described herein. The device 700 may support wireless communication with one or more network entities 102, UEs 104, or any combination thereof.

The device 700 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 702, a memory 704, a transceiver 706, and, optionally, an I/O controller 708. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0086] The processor 702, the memory 704, the transceiver 706, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. For example, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may support a method for performing one or more of the operations described herein.

[0087] In some implementations, the processor 702, the memory 704, the transceiver 706, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 702 and the memory 704 coupled with the processor 702 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 702, instructions stored in the memory 704).

[0088] For example, the processor 702 may support wireless communication at the device 700 in accordance with examples as disclosed herein. The processor 702 may be configured to operable to support a means for determining a transmission resource for a groupcast transmission, based on a number of candidate PSFCH resources associated with the groupcast transmission and a number of group members communicating with the UE; a means for performing the groupcast transmission based on the transmission resource; and a means for receiving, from the group members, positive-negative acknowledgement for the groupcast transmission.

[0089] The processor 702 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 702 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 702. The processor 702 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 704) to cause the device 700 to perform various functions of the present disclosure.

[0090] The memory 704 may include random access memory (RAM) and read-only memory (ROM). The memory 704 may store computer-readable, computer-executable code including instructions that, when executed by the processor 702 cause the device 700 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 702 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some implementations, the memory 704 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[0091] The I/O controller 708 may manage input and output signals for the device 700. The I/O controller 708 may also manage peripherals not integrated into the device M02. In some implementations, the I/O controller 708 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 708 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller 708 may be implemented as part of a processor, such as the processor 706. In some implementations, a user may interact with the device 700 via the I/O controller 708 or via hardware components controlled by the I/O controller 708.

[0092] In some implementations, the device 700 may include a single antenna 710. However, in some other implementations, the device 700 may have more than one antenna 710 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 706 may communicate bi-directionally, via the one or more antennas 710, wired, or wireless links as described herein. For example, the transceiver 706 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver 706 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 710 for transmission, and to demodulate packets received from the one or more antennas 710. The transceiver 706 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[0093] A transmit chain may be configured to generate and transmit signals (e.g., control information, data, packets). The transmit chain may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmit chain may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmit chain may also include one or more antennas 710 for transmitting the amplified signal into the air or wireless medium.

[0094] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 710 for receiving the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0095] FIG. 8 illustrates an example of a processor 800 that supports PSFCH transmissions on an unlicensed spectrum in accordance with aspects of the present disclosure. The processor 800 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 800 may include a controller 802 configured to perform various operations in accordance with examples as described herein. The processor 800 may optionally include at least one memory 804, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 800 may optionally include one or more arithmetic-logic units (ALUs) 800. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0096] The processor 800 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 800) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0097] The controller 802 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 800 to cause the processor 800 to support various operations of a base station in accordance with examples as described herein. For example, the controller 802 may operate as a control unit of the processor 800, generating control signals that manage the operation of various components of the processor 800. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0098] The controller 802 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 804 and determine subsequent instruction(s) to be executed to cause the processor 800 to support various operations in accordance with examples as described herein. The controller 802 may be configured to track memory address of instructions associated with the memory 804. The controller 802 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 802 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 800 to cause the processor 800 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 802 may be configured to manage flow of data within the processor 800. The controller 802 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 800.

[0099] The memory 804 may include one or more caches (e.g., memory local to or included in the processor 800 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 804 may reside within or on a processor chipset (e.g., local to the processor 800). In some other implementations, the memory 804 may reside external to the processor chipset (e.g., remote to the processor 800).

[00100] The memory 804 may store computer-readable, computer-executable code including instructions that, when executed by the processor 800, cause the processor 800 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 802 and/or the processor 800 may be configured to execute computer-readable instructions stored in the memory 804 to cause the processor 800 to perform various functions. For example, the processor 800 and/or the controller 802 may be coupled with or to the memory 804, and the processor 800, the controller 802, and the memory 804 may be configured to perform various functions described herein. In some examples, the processor 800 may include multiple processors and the memory 804 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[00101] The one or more ALUs 800 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 800 may reside within or on a processor chipset (e.g., the processor 800). In some other implementations, the one or more ALUs 800 may reside external to the processor chipset (e.g., the processor 800). One or more ALUs 800 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 800 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 800 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 800 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 800 to handle conditional operations, comparisons, and bitwise operations.

[00102] The processor 800 may support wireless communication in accordance with examples as disclosed herein. The processor 800 may be configured to or operable to support a means for determining a transmission resource for a groupcast transmission, based on a number of candidate PSFCH resources associated with the groupcast transmission and a number of group members communicating with the UE; a means for performing the groupcast transmission based on the transmission resource; and a means for receiving, from the group members, positive-negative acknowledgement for the groupcast transmission.

[00103] It should be noted that the methods described herein describes possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[00104] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00105] The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

[00106] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[00107] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[00108] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

WHAT IS CLAIMED IS:

1. A user equipment (UE) comprising:

at least one memory; and

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

determine a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE;

perform the groupcast transmission based on the transmission resource; and

receive, from the group members, positive-negative acknowledgement for the groupcast transmission.

2. The UE of claim 1, wherein determining the transmission resource comprises:

selecting, from one or more candidate resource pools configured with candidate PSFCH resources, a resource pool configured with a PSFCH occupying a dedicated interlace, based on determining that the number of candidate PSFCH resources of the resource pool is greater than or equal to the number of group members.

3. The UE of claim 2, wherein determining the transmission resource comprises:

determining a frequency domain resource for the groupcast transmission as a plurality of subchannels, the number of candidate PSFCH resources associated with the plurality of subchannels being greater than or equal to the number of group members.

4. The UE of claim 2, wherein a period of the candidate PSFCH resources comprises a first plurality of slots, and wherein determining the transmission resource comprises:

determining a time domain resource for the groupcast transmission as a second plurality of slots, the candidate PSFCH resources associated with the second plurality of slots being in a same PSFCH transmission occasion.

5. The UE of claim 4, wherein the groupcast transmission in the second plurality of slots occupies a same subchannel in a frequency domain.

6. The UE of claim 4, wherein the candidate PSFCH resources associated with the second plurality of slots are used by the group members in the PSFCH transmission occasion.

7. The UE of claim 4, wherein a number of the first plurality of slots is the same as a number of the second plurality of slots.

8. The UE of claim 2, wherein the processor is further configured to cause the UE to:

apply an orthogonal cover code (OCC) sequence within the dedicated interlace.

9. The UE of claim 8, wherein the OCC sequence is applied to a plurality of consecutive resource blocks (RBs) within the dedicated interlace.

10. The UE of claim 9, wherein the OCC sequence is not applied to remaining one or more RBs if a number of the remaining one or more RBs is smaller than a length of the OCC sequence, the remaining one or more RBs being determined by excluding the plurality of consecutive RBs from the dedicated interlace.

11. The UE of claim 10, wherein receiving the positive-negative acknowledgement comprises:

performing no detection for the positive-negative acknowledgement on the remaining one or more RBs.

12. The UE of claim 8, wherein the processor is further configured to cause the UE to:

transmit, to the group members in sidelink control information (SCI), an indication indicating at least one of the following:

a length of the OCC sequence; or

whether to apply the OCC sequence.

13. The UE of claim 2, wherein the processor is further configured to cause the UE to:

map a long sequence for the PSFCH to a first plurality of RBs within the dedicated interlace, the long sequence occupying a second plurality of RBs.

14. The UE of claim 13, wherein receiving positive-negative acknowledgement comprises:

performing no detection for the positive-negative acknowledgement on remaining one or more RBs if a number of the remaining one or more RBs is smaller than a number of the second plurality of RBs, the remaining one or more RBs being determined by excluding the first plurality of RBs from the dedicated interlace.

15. The UE of claim 13, wherein a number of the second plurality of RBs is pre-defined or indicated in an SCI.

16. The UE of claim 13, wherein a number of the second plurality of RBs is configured per resource pool.

17. A processor for wireless communication, comprising:

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

determine a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE;

perform the groupcast transmission based on the transmission resource; and

receive, from the group members, positive-negative acknowledgement for the groupcast transmission.

18. A method performed by a user equipment (UE), comprising:

determining a transmission resource for a groupcast transmission, based on a number of candidate physical sidelink feedback channel (PSFCH) resources associated with the groupcast transmission and a number of group members communicating with the UE;

performing the groupcast transmission based on the transmission resource; and

receiving, from the group members, positive-negative acknowledgement for the groupcast transmission.

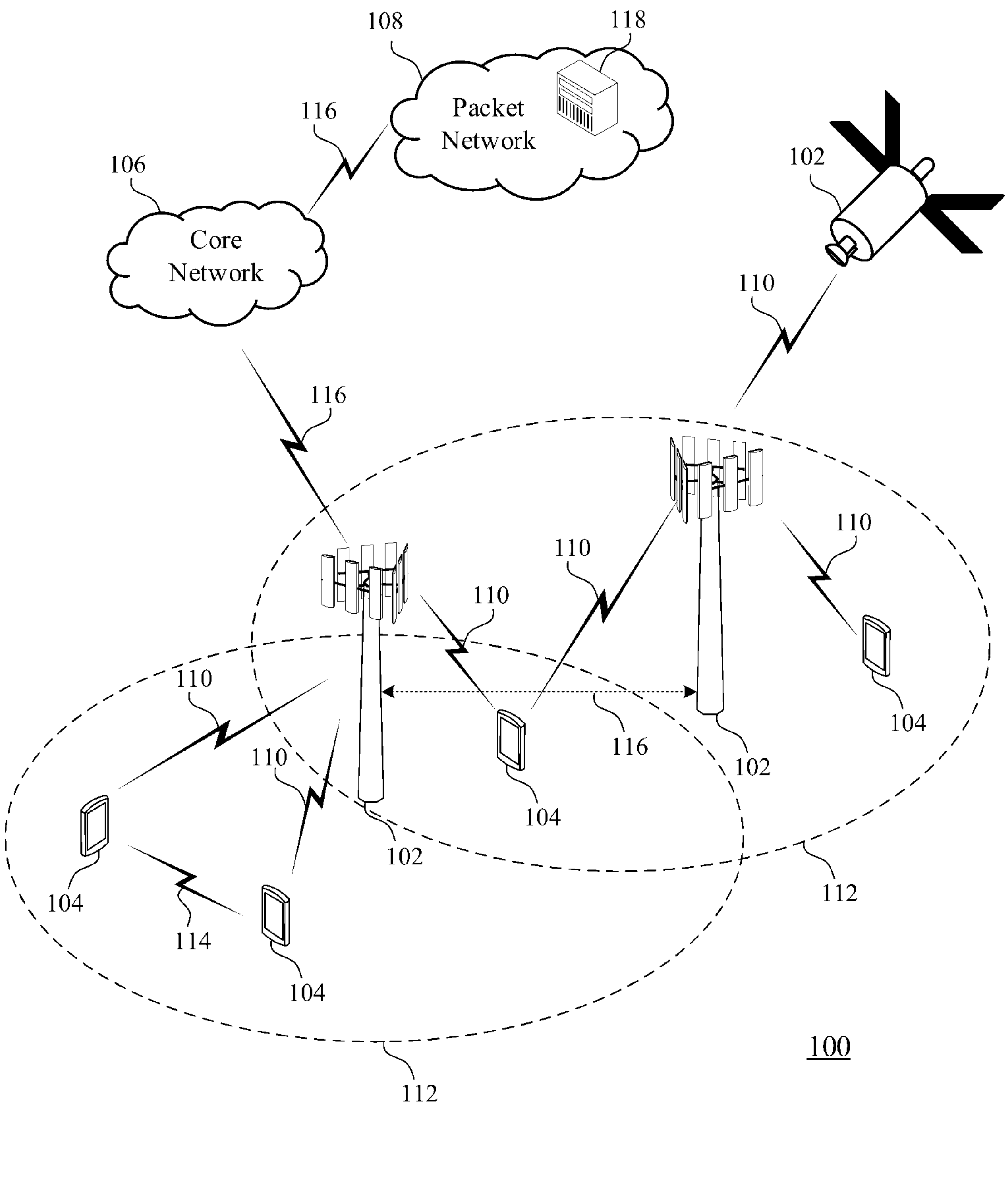
108
118
116
Packet
Network
102
106
Core
Network
110
116
110
110
110
110
110
104
116
102
104
110
104
102
112
104
114
104
100
112

FIG. 1

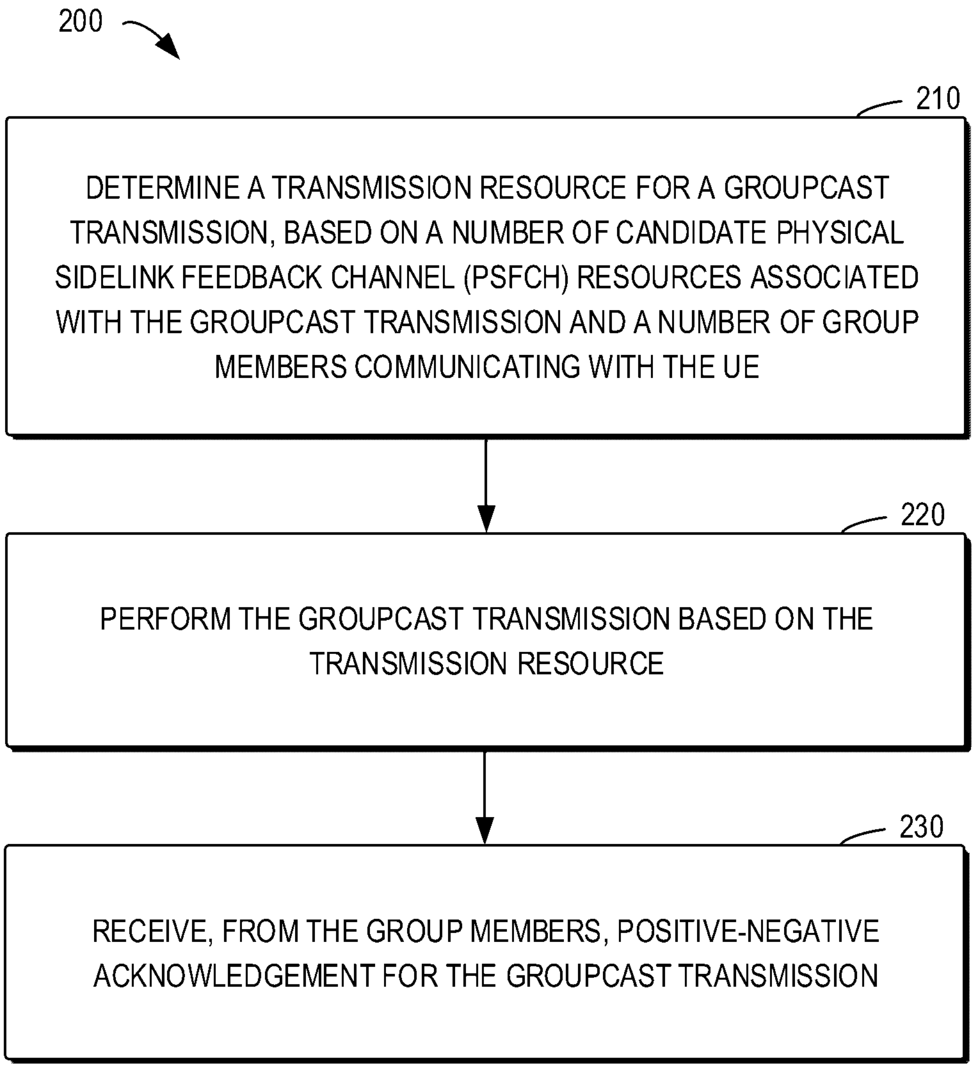
200
210
DETERMINE A TRANSMISSION RESOURCE FOR A GROUPCAST TRANSMISSION, BASED ON A NUMBER OF CANDIDATE PHYSICAL SIDELINK FEEDBACK CHANNEL (PSFCH) RESOURCES ASSOCIATED WITH THE GROUPCAST TRANSMISSION AND A NUMBER OF GROUP MEMBERS COMMUNICATING WITH THE UE
220
PERFORM THE GROUPCAST TRANSMISSION BASED ON THE TRANSMISSION RESOURCE
230
RECEIVE, FROM THE GROUP MEMBERS, POSITIVE-NEGATIVE ACKNOWLEDGEMENT FOR THE GROUPCAST TRANSMISSION

FIG. 2

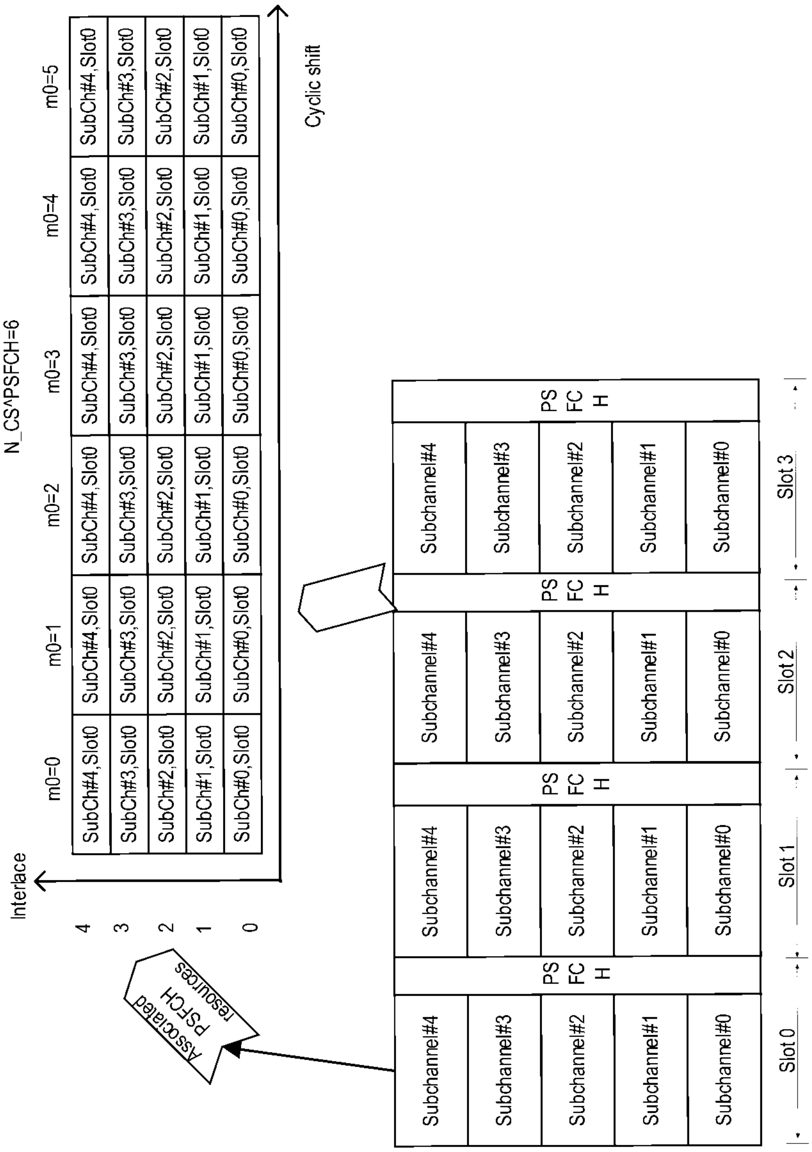
N_CS^PSFCH=6
m0=0
m0=1
m0=2
m0=3
m0=4
m0=5
SubCh#4,Slot0
SubCh#3,Slot0
SubCh#2,Slot0
SubCh#1,Slot0
SubCh#0,Slot0
Interlace
Cyclic shift
4
3
2
1
0
Associated PSFCH resources
Subchannel#4
Subchannel#3
Subchannel#2
Subchannel#1
Subchannel#0
PSFCH
Slot 0
Slot 1
Slot 2
Slot 3

FIG. 3

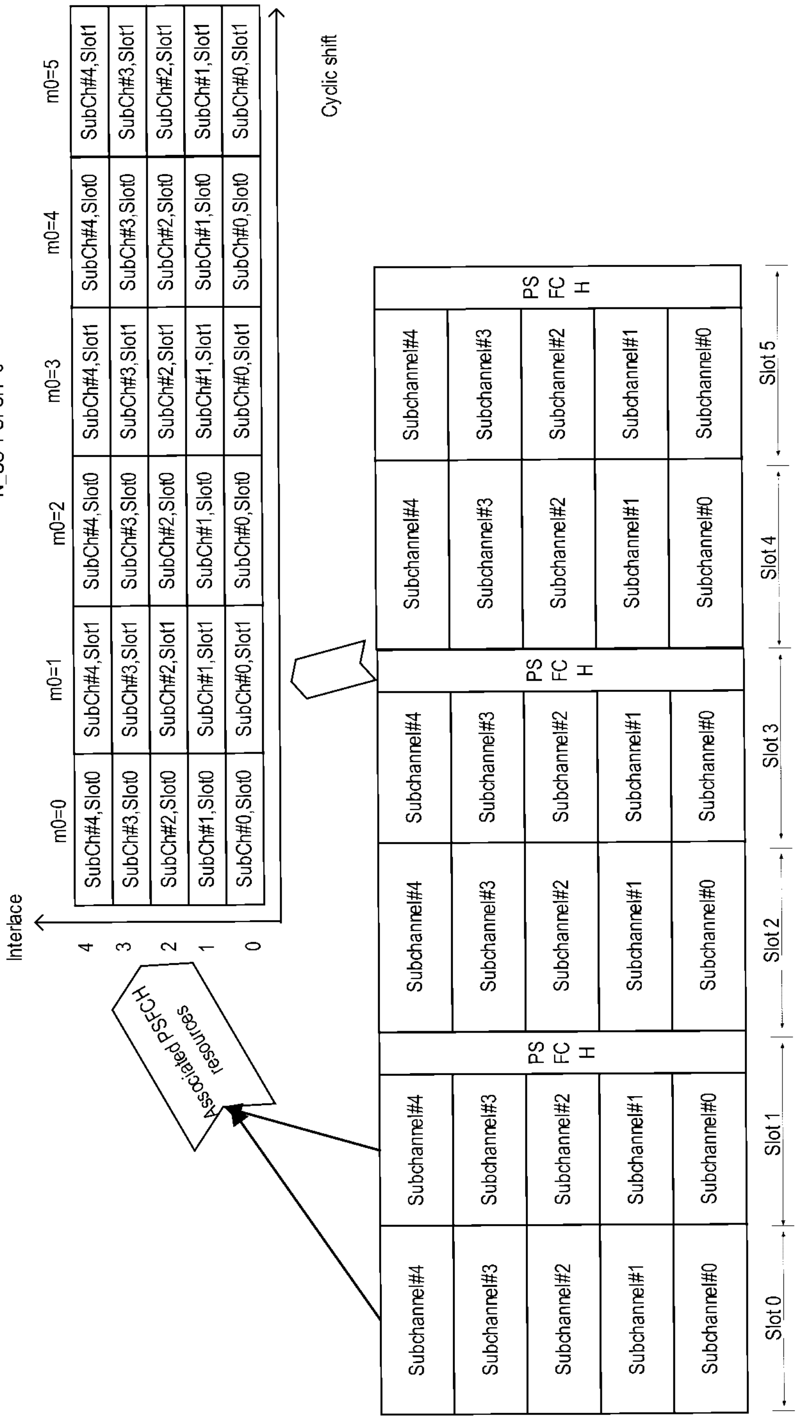
N_CS^PSFCH=6
m0=0
m0=1
m0=2
m0=3
m0=4
m0=5
SubCh#4,Slot0
SubCh#4,Slot1
SubCh#3,Slot0
SubCh#3,Slot1
SubCh#2,Slot0
SubCh#2,Slot1
SubCh#1,Slot0
SubCh#1,Slot1
SubCh#0,Slot0
SubCh#0,Slot1
Interlace
4
3
2
1
0
Cyclic shift
Associated PSFCH resources
Subchannel#4
Subchannel#3
Subchannel#2
Subchannel#1
Subchannel#0
PS FC H
Slot 0
Slot 1
Slot 2
Slot 3
Slot 4
Slot 5

FIG. 4

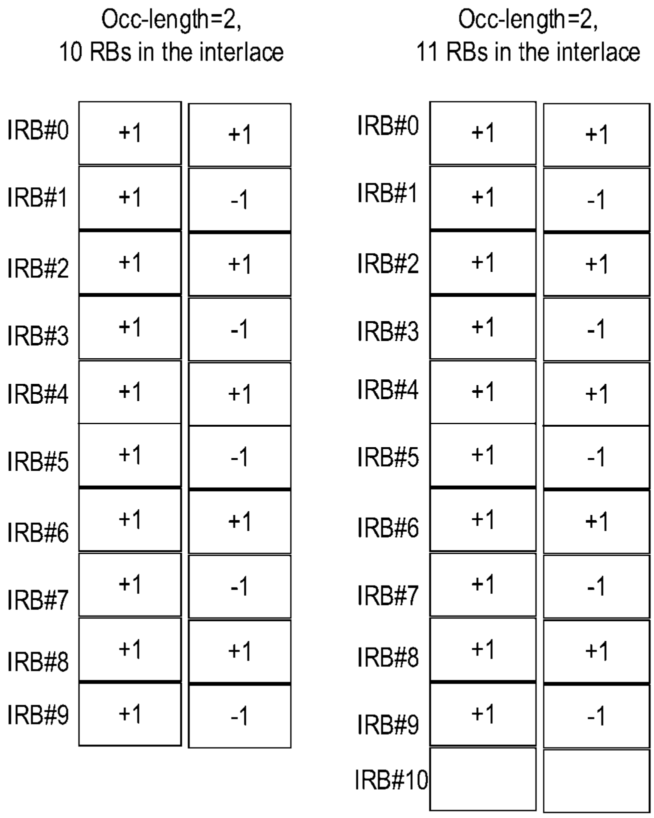
Occ-length=2,
10 RBs in the interlace
Occ-length=2,
11 RBs in the interlace
IRB#0
IRB#1
IRB#2
IRB#3
IRB#4
IRB#5
IRB#6
IRB#7
IRB#8
IRB#9
IRB#10
+1
-1

FIG. 5A

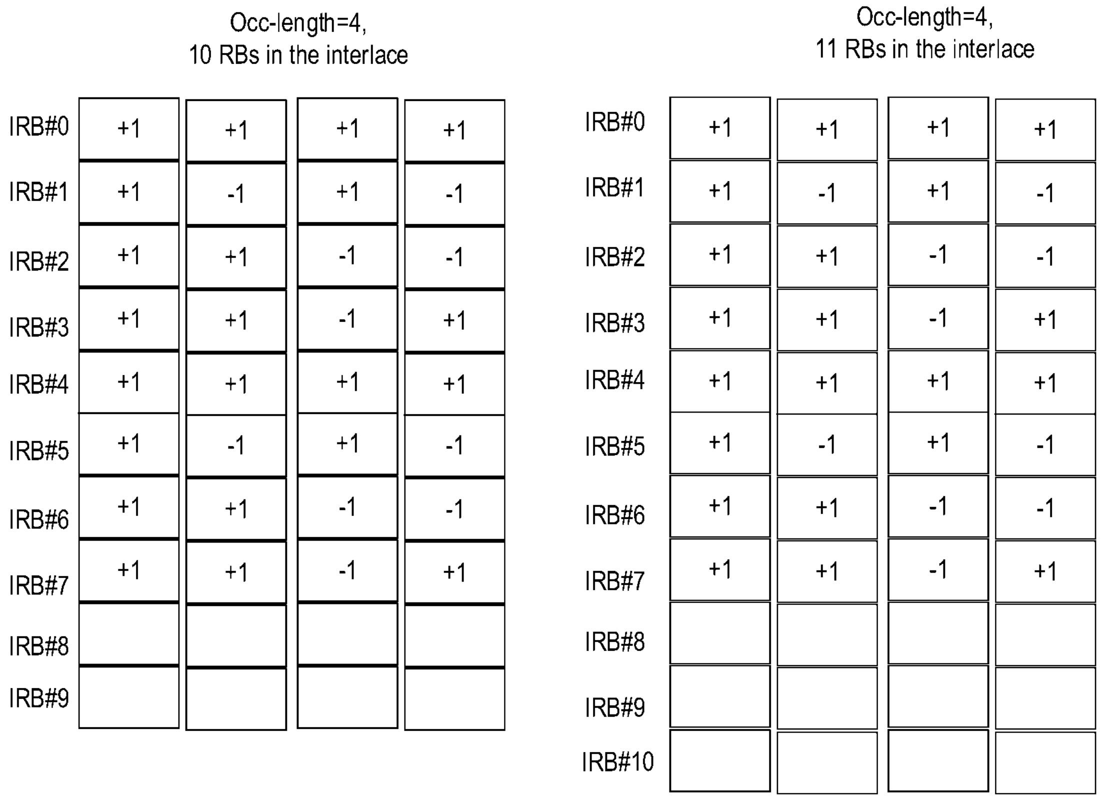
Occ-length=4,
10 RBs in the interlace
IRB#0 +1 +1 +1 +1
IRB#1 +1 -1 +1 -1
IRB#2 +1 +1 -1 -1
IRB#3 +1 +1 -1 +1
IRB#4 +1 +1 +1 +1
IRB#5 +1 -1 +1 -1
IRB#6 +1 +1 -1 -1
IRB#7 +1 +1 -1 +1
IRB#8
IRB#9
Occ-length=4,
11 RBs in the interlace
IRB#0 +1 +1 +1 +1
IRB#1 +1 -1 +1 -1
IRB#2 +1 +1 -1 -1
IRB#3 +1 +1 -1 +1
IRB#4 +1 +1 +1 +1
IRB#5 +1 -1 +1 -1
IRB#6 +1 +1 -1 -1
IRB#7 +1 +1 -1 +1
IRB#8
IRB#9
IRB#10

FIG. 5B

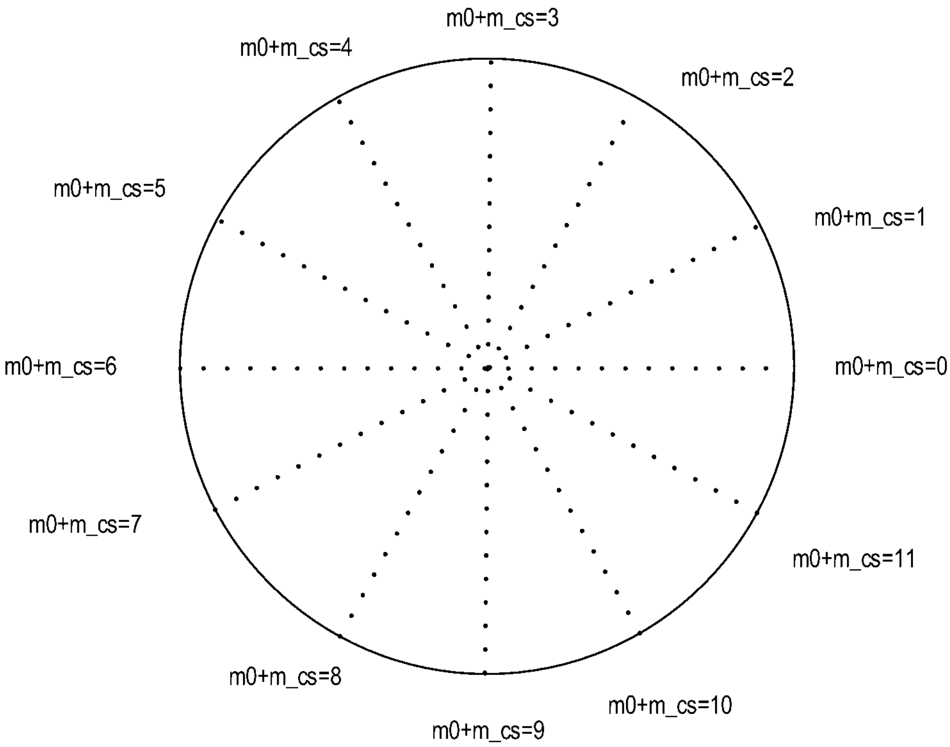
m0+m_cs=3
m0+m_cs=4
m0+m_cs=2
m0+m_cs=5
m0+m_cs=1
m0+m_cs=6
m0+m_cs=0
m0+m_cs=7
m0+m_cs=11
m0+m_cs=8
m0+m_cs=10
m0+m_cs=9

FIG. 6A

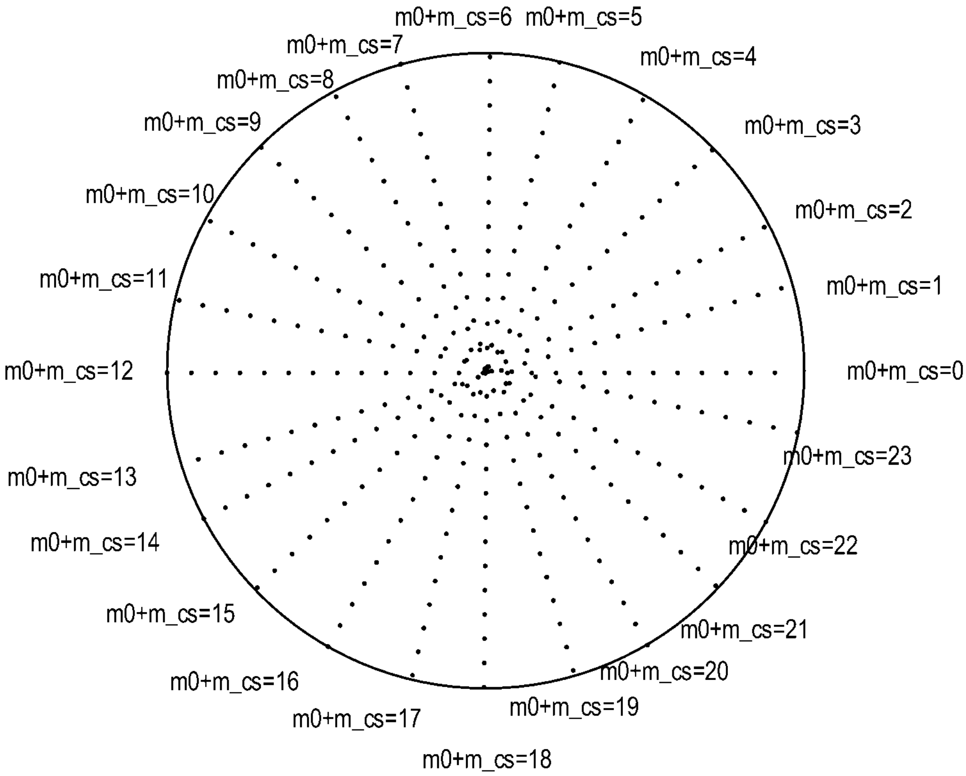
m0+m_cs=6
m0+m_cs=5
m0+m_cs=7
m0+m_cs=4
m0+m_cs=8
m0+m_cs=9
m0+m_cs=3
m0+m_cs=10
m0+m_cs=2
m0+m_cs=11
m0+m_cs=1
m0+m_cs=12
m0+m_cs=0
m0+m_cs=23
m0+m_cs=13
m0+m_cs=14
m0+m_cs=22
m0+m_cs=15
m0+m_cs=21
m0+m_cs=20
m0+m_cs=16
m0+m_cs=19
m0+m_cs=17
m0+m_cs=18

FIG. 6B

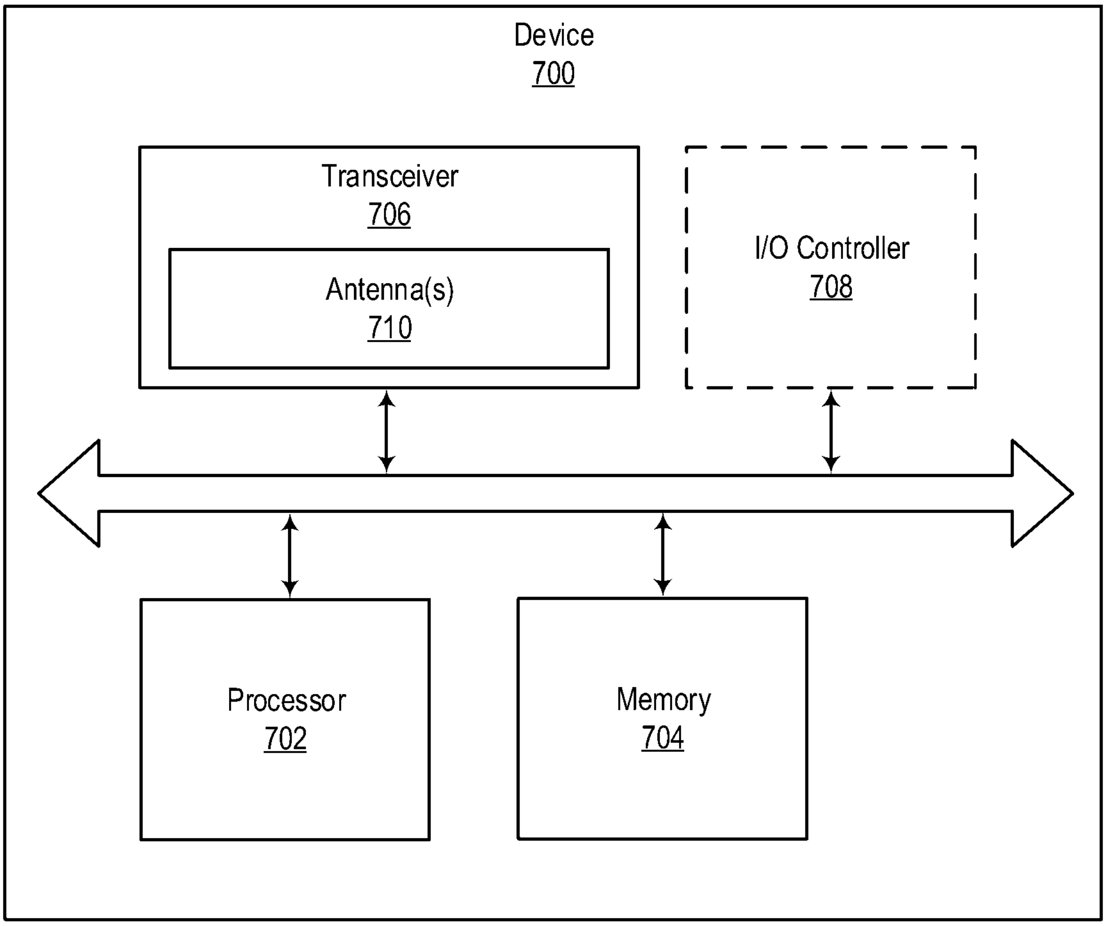
Device
700
Transceiver
706
Antenna(s)
710
I/O Controller
708
Processor
702
Memory
704

FIG. 7

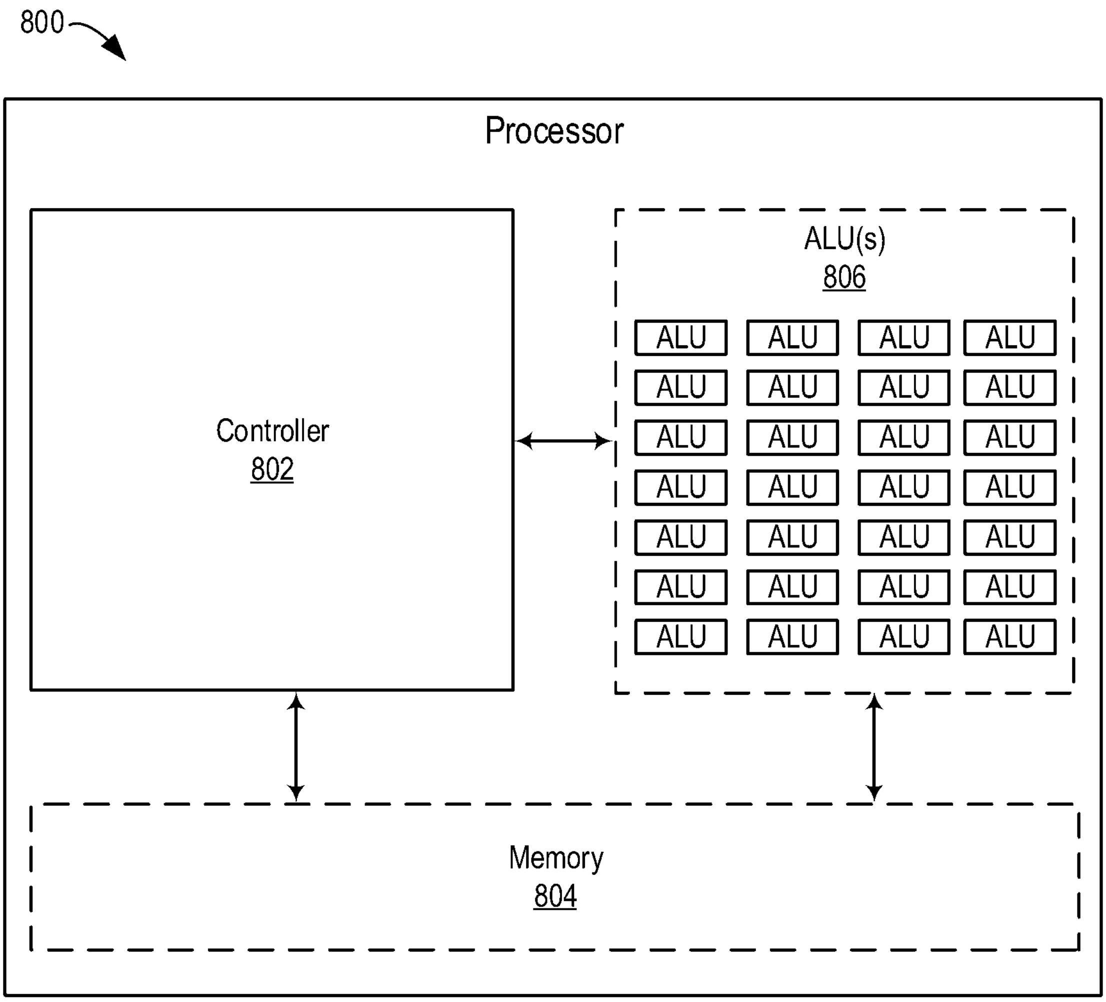
800
Processor
Controller
802
ALU(s)
806
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
ALU ALU ALU ALU
Memory
804

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2023/110236

A. CLASSIFICATION OF SUBJECT MATTER

H04W 4/08(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)

IPC: H04W

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)

CNTXT,ENTXTC,DWPI,VEN,3GPP: HARQ, unlicensed, PSFCH, groupcast, multicast, candidate, physical, sidelink, feedback, channel, resource?, group, member?, acknowledgement, slot, subchannel?, occasion, ACK, NACK, NUM_GP, V2X, pool, option, 2, num+, size

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021030992 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 25 February 2021 (2021-02-25) description, paragraphs 23 and 220-248	1,17-18
X	CN 111865504 A (BEIJING SAMSUNG COMMUNICATION TECHNOLOGY et al.) 30 October 2020 (2020-10-30) description, paragraphs 224-252	1,17-18
A	CN 110445586 A (SPREADTRUM COMMUNICATIONS (SHANGHAI) INC.) 12 November 2019 (2019-11-12) the whole document	1-18
A	LENOVO et al. "Discussion on physical layer procedures for NR sidelink" *3GPP TSG RAN WG1 #99 R1-1912325,* 22 November 2019 (2019-11-22), the whole document	1-18

☐ 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
"D" document cited by the applicant in the international application
"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
23 January 2024	**23 February 2024**

Name and mailing address of the ISA/CN	Authorized officer
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2023/110236

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2021030992	A1	25 February 2021	CN	114128327	A	01 March 2022
CN	111865504	A	30 October 2020	WO	2020222568	A1	05 November 2020
				KR	20210149876	A	09 December 2021
				EP	3949208	A1	09 February 2022
				US	2022210768	A1	30 June 2022
CN	110445586	A	12 November 2019		None		