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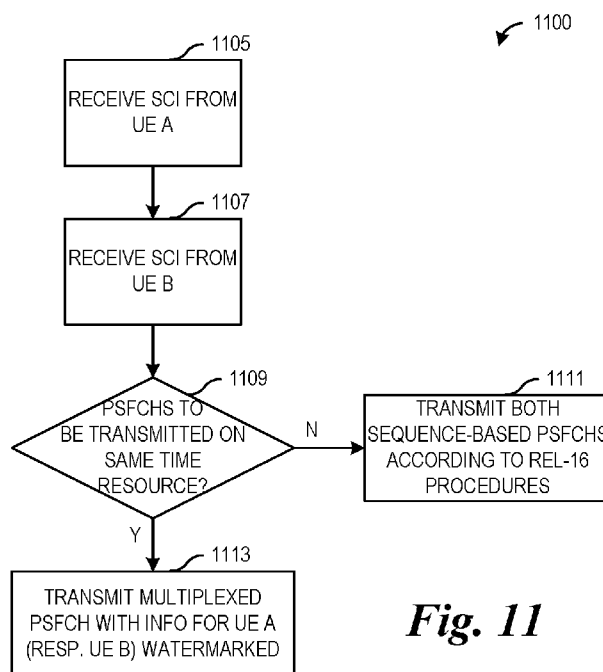


Fig. 11

(57) Abstract: A method includes determining a first sidelink feedback resource in accordance with a first sidelink transmission received from a second user equipment (UE), the first sidelink feedback resource comprising a first frequency resource and a first time resource, the first sidelink feedback resource being associated with a first sidelink feedback message responsive to the first sidelink transmission; determining a second sidelink feedback resource in accordance with a second sidelink transmission received from a third UE, the second sidelink feedback resource comprising a second frequency resource and the first time resource, the second sidelink feedback resource being associated with a second sidelink feedback message responsive to the second sidelink transmission; multiplexing the first sidelink feedback message and the second sidelink feedback message; and transmitting the multiplexed first and second sidelink feedback messages in a third frequency resource.

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Methods and Apparatus for Feedback in Sidelink Communications

This application claims the benefit of U.S. Provisional Application No. 62/932,252, filed on November 7, 2019, entitled "Methods and Apparatus for Feedback for Sidelink Communications," which application is hereby incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present disclosure relates generally to methods and apparatus for digital communications, and, in particular embodiments, to methods and apparatus for feedback in sidelink communications.

BACKGROUND

It is expected that vehicle-to-everything (V2X) communications will play an essential role in the evolution of the automotive industry in the near future and revolutionize the field. Dedicated short-range communication (DSRC) by IEEE and the long-term evolution – vehicular (LTE-V) developed by 3GPP are two major vehicular communication technologies developed thus far.

The third generation partnership project (3GPP) has also approved a work item for the standardization of the fifth generation (5G) new radio access technology (NR) vehicle-to-everything (V2X) wireless communication with the goal of providing 5G-compatible high-speed reliable connectivity for vehicular communications in the near future for applications such as safety systems and autonomous driving. High data rates, low latencies and high reliabilities are some of the key areas that are being investigated and standardized.

One of the main features being introduced for NR V2X communication is unicast communications on the sidelink at the lower layers along with hybrid automatic repeat request (HARQ) to provide high reliability. HARQ for NR V2X is supported by a feedback channel, referred to as the physical sidelink feedback channel (PSFCH) at the physical layer. In order to ensure that HARQ can be performed in an effective manner, it is crucial for messages carried in the PSFCH to be received reliably.

Therefore, there is a need for methods and apparatus for addressing issues related to the reliability of the feedback channel when having to simultaneously transmit HARQ feedback to multiple UEs or multiple HARQ feedbacks to a single UE.

SUMMARY

According to a first aspect, a method implemented by a first user equipment (UE) is provided. The method comprising: determining, by the first UE, a first sidelink feedback resource in accordance with a first sidelink transmission received from a second UE, the
5 first sidelink feedback resource comprising a first frequency resource and a first time resource, the first sidelink feedback resource being associated with a transmission of a first sidelink feedback message responsive to the first sidelink transmission;
determining, by the first UE, a second sidelink feedback resource in accordance with a second sidelink transmission received from a third UE, the second sidelink feedback
10 resource comprising a second frequency resource and the first time resource, the second sidelink feedback resource being associated with a transmission of a second sidelink feedback message responsive to the second sidelink transmission; multiplexing, by the first UE, the first sidelink feedback message and the second sidelink feedback message;
and transmitting, by the first UE, the multiplexed first and second sidelink feedback
15 messages in a third frequency resource.

In a first implementation form of the method according to the first aspect, further comprising: scrambling, by the first UE, the first sidelink feedback message with a first scrambling code associated with the second UE; and scrambling, by the first UE, the
20 second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before the multiplexing.

In a second implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, the first scrambling code being associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

25 In a third implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of the first time resource.

In a fourth implementation form of the method according to the first aspect or any
30 preceding implementation form of the first aspect, further comprising transmitting, by the first UE, a message including an indication of the third frequency resource used to transmit the first sidelink feedback message and the second sidelink feedback message.

In a fifth implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, the message further comprising an indication of a second time resource, and the multiplexed first and second sidelink feedback messages being transmitting in the third frequency resource of the second time resource.

In a sixth implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of a third time resource, the third time resource being associated with the transmission of the message.

In a seventh implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, determining the first sidelink feedback resource comprising receiving a first sidelink control information (SCI) message including an indication of the first sidelink feedback resource, and determining the second sidelink feedback resource comprising receiving a second SCI message including an indication of the second sidelink feedback resource.

In an eighth implementation form of the method according to the first aspect or any preceding implementation form of the first aspect, further comprising: determining, by the first UE, a third sidelink feedback resource in accordance with a third sidelink transmission received from a fourth UE, the third sidelink feedback resource comprising a fourth frequency resource and a fourth time resource, the third sidelink feedback resource being associated with a transmission of a third sidelink feedback message responsive to the third sidelink transmission; and determining, by the first UE, that the first time resource and the fourth time resource are different time resources, and based thereon: transmitting, by the first UE, the third sidelink feedback message in the fourth frequency resource of the fourth time resource.

According to a second aspect, a method implemented by a first UE is provided. The method comprising: receiving, by the first UE from a second UE, a first indicator of a first sidelink feedback resource associated with a transmission of a first sidelink feedback message responsive to a sidelink transmission received from the second UE, the first sidelink feedback resource comprising a first frequency resource and a first time resource; receiving, by the first UE from a third UE, a second indicator of a second sidelink feedback resource associated with a transmission of a second sidelink feedback message responsive to a sidelink transmission received from the third UE, the second

sidelink feedback resource comprising a second frequency resource and a second time resource; and determining, by the first UE, that the first time resource and the second time resource are the same, and based thereon: determining, by the first UE, a frequency resource in accordance with an identifier of the first UE; multiplexing, by the first UE,
5 the first sidelink feedback message and the second sidelink feedback message; and transmitting, by the first UE, the multiplexed first and second sidelink feedback messages in the frequency resource.

In a first implementation form of the method according to the second aspect, further comprising: scrambling, by the first UE, the first sidelink feedback message with a first
10 scrambling code associated with the second UE; and scrambling, by the first UE, the second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before the multiplexing.

In a second implementation form of the method according to the second aspect or any preceding implementation form of the second aspect, the first scrambling code being
15 associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

In a third implementation form of the method according to the second aspect or any preceding implementation form of the second aspect, the first indicator being received in a first SCI message, and the second indicator being received in a second SCI message.

20 In a fourth implementation form of the method according to the second aspect or any preceding implementation form of the second aspect, the multiplexed first and second sidelink feedback messages being transmitted in the frequency resource of the first time resource.

According to a third aspect, a first UE is provided. The first UE comprising: one or more
25 processors; and a non-transitory memory storage comprising instructions that, when executed by the one or more processors, cause the first UE to: determine a first sidelink feedback resource in accordance with a first sidelink transmission received from a second UE, the first sidelink feedback resource comprising a first frequency resource and a first time resource, the first sidelink feedback resource being associated with a transmission
30 of a first sidelink feedback message responsive to the first sidelink transmission; determine a second sidelink feedback resource in accordance with a second sidelink transmission received from a third UE, the second sidelink feedback resource comprising a second frequency resource and the first time resource, the second sidelink feedback

resource being associated with a transmission of a second sidelink feedback message responsive to the second sidelink transmission; multiplex the first sidelink feedback message and the second sidelink feedback message; and transmit the multiplexed first and second sidelink feedback messages in a third frequency resource.

- 5 In a first implementation form of the first UE according to the third aspect, the instructions further causing the first UE to scramble the first sidelink feedback message with a first scrambling code associated with the second UE; and scramble, by the first UE, the second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before multiplexing the first sidelink feedback
10 message and the second sidelink feedback message.

In a second implementation form of the first UE according to the third aspect or any preceding implementation form of the third aspect, the first scrambling code being associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

- 15 In a third implementation form of the first UE according to the third aspect or any preceding implementation form of the third aspect, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of the first time resource.

- In a fourth implementation form of the first UE according to the third aspect or any
20 preceding implementation form of the third aspect, the instructions further causing the first UE to transmit a message including an indication of the third frequency resource used to transmit the first sidelink feedback message and the second sidelink feedback message.

- In a fifth implementation form of the first UE according to the third aspect or any
25 preceding implementation form of the third aspect, the message further comprising an indication of a second time resource, and the multiplexed first and second sidelink feedback messages being transmitting in the third frequency resource of the second time resource.

- In a sixth implementation form of the first UE according to the third aspect or any
30 preceding implementation form of the third aspect, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of a third

time resource, the third time resource being associated with the transmission of the message.

In a seventh implementation form of the first UE according to the third aspect or any preceding implementation form of the third aspect, the instructions further causing the
5 first UE to receive a first SCI message including an indication of the first sidelink feedback resource and to receive a second SCI message including an indication of the second sidelink feedback resource.

In an eighth implementation form of the first UE according to the third aspect or any preceding implementation form of the third aspect, the instructions further causing the
10 first UE to determine a third sidelink feedback resource in accordance with a third sidelink transmission received from a fourth UE, the third sidelink feedback resource comprising a fourth frequency resource and a fourth time resource, the third sidelink feedback resource being associated with a transmission of a third sidelink feedback message responsive to the third sidelink transmission; and determine that the first time
15 resource and the fourth time resource are different time resources, and based thereon: transmit the third sidelink feedback message in the fourth frequency resource of the fourth time resource.

According to a fourth aspect, first UE is provided. The first UE comprising: one or more processors; and a non-transitory memory storage comprising instructions that, when
20 executed by the one or more processors, cause the first UE to: receive, from a second UE, a first indicator of a first sidelink feedback resource associated with a transmission of a first sidelink feedback message responsive to a sidelink transmission received from the second UE, the first sidelink feedback resource comprising a first frequency resource and a first time resource; receive, from a third UE, a second indicator of a second sidelink
25 feedback resource associated with a transmission of a second sidelink feedback message responsive to a sidelink transmission received from the third UE, the second sidelink feedback resource comprising a second frequency resource and a second time resource; and determine that the first time resource and the second time resource are the same, and based thereon: determine a frequency resource in accordance with an identifier of
30 the first UE; multiplex the first sidelink feedback message and the second sidelink feedback message; and transmit the multiplexed first and second sidelink feedback messages in the frequency resource.

In a first implementation form of the first UE according to the fourth aspect, the instructions further causing the first UE to scramble the first sidelink feedback message

with a first scrambling code associated with the second UE; and scramble the second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before multiplexing the first sidelink feedback message and the second sidelink feedback message.

- 5 In a second implementation form of the first UE according to the fourth aspect or any preceding implementation form of the fourth aspect, the first scrambling code being associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

- 10 In a third implementation form of the first UE according to the fourth aspect or any preceding implementation form of the fourth aspect, the first indicator being received in a first SCI message, and the second indicator being received in a second SCI message.

- In a fourth implementation form of the first UE according to the fourth aspect or any preceding implementation form of the fourth aspect, the multiplexed first and second sidelink feedback messages being transmitted in the frequency resource of the first time
15 resource.

An advantage of a preferred embodiment is that high in-band emission (IBE) is reduced in situations simultaneous hybrid automatic repeat request (HARQ) feedback transmissions are occurring to multiple UEs, which may result in better HARQ feedback decoding performance.

20 BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

- 25 Figure 1 illustrates a diagram highlighting example vehicle-to-everything (V2X) communications types;

Figure 2A illustrates a diagram of an example in-coverage (IC) situation;

Figure 2B illustrates a diagram of an example out-of-coverage (OOC) situation

Figure 3 illustrates a diagram of an example resource grid, highlighting a resource pool (RP);

Figure 4 illustrates a diagram of an example PSFCH configuration with parameters N , K , and X in a RP

Figure 5 illustrates a diagram of a resulting mapping of PSSCH resources to the corresponding PSFCH

- 5 Figure 6 illustrates a diagram of a communications system highlighting a communications situation of interest

Figure 7 illustrates a diagram highlighting a high in-band emission (IBE) situation

- Figure 8 illustrates a flow diagram of example operations occurring at a device transmitting the physical sidelink feedback channel (PSFCH) according to example
10 embodiments presented herein;

Figure 9 illustrates a flow diagram of example operations occurring at a device receiving the PSFCH when multiplexed PSFCHs are indicated in a SCI according to example embodiments presented herein;

- Figure 10 illustrates a flow diagram of example operations occurring at a device receiving
15 the PSFCH when frequency resources of the multiplexed PSFCH are pre-configured according to example embodiments presented herein;

Figure 11 illustrates a flow diagram of example operations occurring at a device transmitting a scrambled PSFCH according to example embodiments presented herein;

- Figure 12 illustrates a flow diagram of example operations occurring at a device receiving
20 the scrambled PSFCH according to example embodiments presented herein;

Figure 13A illustrates a diagram of PSFCH duplication with multiplexing according to example embodiments presented herein;

Figure 13B illustrates a diagram of PSFCH duplication with unicasts and groupcasts according to example embodiments presented herein;

- 25 Figure 14 illustrates a flow diagram of example operations occurring at a device transmitting the PSFCH, where an indication of the PSFCH location is transmitted by the device transmitting the PSFCH, along with an indication of the scrambling sequence used to scramble the multiplexed PSFCH according to example embodiments presented herein;

Figure 15 illustrates a flow diagram of example operations occurring at a device receiving the multiplexed PSFCH, where an indication of the PSFCH location and an indication of the scrambling sequence used to scramble the PSFCH are also received by the device according to example embodiments presented herein;

- 5 Figure 16 illustrates an example communication system according to example embodiments presented herein;

Figures 17A and 17B illustrate example devices that may implement the methods and teachings according to this disclosure; and

- 10 Figure 18 is a block diagram of a computing system that may be used for implementing the devices and methods disclosed herein.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

- The structure and use of disclosed embodiments are discussed in detail below. It should be appreciated, however, that the present disclosure provides many applicable concepts that can be embodied in a wide variety of specific contexts. The specific embodiments
15 discussed are merely illustrative of specific structure and use of embodiments, and do not limit the scope of the disclosure.

- Vehicle-to-everything (V2X) communications constitute communications on a sidelink between devices such as user equipment (UEs) in addition to downlink and uplink communications. Downlink refers to communication from an access node to a device
20 (e.g., user equipment (UE)). Uplink refers to communication from a device (e.g., user equipment (UE)) to an access node. Access nodes may also be commonly referred to as Node Bs, evolved Node Bs (eNBs), next generation (NG) Node Bs (gNBs), master eNBs (MeNBs), secondary eNBs (SeNBs), master gNBs (MgNBs), secondary gNBs (SgNBs), network controllers, control nodes, base stations, access points, transmission points
25 (TPs), transmission-reception points (TRPs), cells, carriers, macro cells, femtocells, pico cells, and so on, while UEs may also be commonly referred to as mobile stations, mobiles, terminals, users, subscribers, stations, and the like. Access nodes may provide wireless access in accordance with one or more wireless communication protocols, e.g., the Third Generation Partnership Project (3GPP) long term evolution (LTE), LTE advanced (LTE-
30 A), 5G, 5G LTE, 5G NR, sixth generation (6G), High Speed Packet Access (HSPA), the IEEE 802.11 family of standards, such as 802.11a/b/g/n/ac/ad/ax/ay/be, etc.

Figure 1 illustrates a diagram 100 highlighting example V2X communications types. The example V2X communications types include vehicle-to-vehicle (V2V) (between vehicles

105 and 107, for example), vehicle-to-pedestrian (V2P) (between vehicle 105 and pedestrian 109, for example), and vehicle-to-Internet (V2I) (between vehicle 105 and network 111, for example). As used herein, a vehicle refers to a communication device or communication devices within the vehicle. As an example, a vehicle may have an integrated UE, or the vehicle may contain a passenger operating a hand-held UE. Hence, the term vehicle may be used interchangeably with UE. In circumstances where confusion may occur, a distinction between vehicle and UE will be made.

The communication can either be in-coverage (IC), or out-of-coverage (OOC): with IC operation, an access node (e.g., eNB, gNB) is present and can be used to manage the sidelink. With OOC operation, the system operation is fully distributed, and UEs select resources on their own.

Figure 2A illustrates a diagram 200 of an example IC situation. As shown in Figure 2A, vehicles 205 and 207 are communicating while within coverage of access node 210. Access node 210 can broadcast configuration information for the sidelink. Figure 2B illustrates a diagram 250 of an example OOC situation. As shown in Figure 2B, vehicles 255 and 257 are communicating while outside of coverage of access nodes.

For the purpose of sidelink communications, the notion of resource pools was introduced for the LTE sidelink, and is being reused for the NR sidelink. A resource pool (RP) is a set of resources that can be used for sidelink communication. Resources in a RP are configured for different channels including control channels, shared channels, feedback channels, synchronization signals, reference signals, broadcast channels (e.g., master information block), and so on. The standard defines rules on how the resources are shared and used for a particular configuration of the RP.

Figure 3 illustrates a diagram of an example resource grid 300, highlighting a RP 305. Resource grid 300 includes time resources, referred to as slots, such as slot 310, and frequency resources, referred to as sub-channels, such as sub-channel 315. A RP for sidelink communications can be configured in units of slots in the time domain and physical resource blocks (PRBs) or sub-channels in the frequency domain. A sub-channel consists of one or more PRBs. Some of resources of resource grid 300 form RP 305, which may be used for a variety of purposes, including sidelink communication. Resources of resource grid 300 forming RP 305 are shown as cross-hatched boxes.

For NR mobile broadband (MBB) applications, each PRB in the grid (such as resource grid 300 shown in Figure 3) is defined as a slot of 14 consecutive orthogonal frequency division multiplexed (OFDM) symbols in the time domain and 12 consecutive subcarriers

in the frequency domain, i.e., each resource block contains 12×14 resource elements (REs). Hence, each PRB (or resource in general) has a time resource (e.g., OFDM symbol, slot, frame, etc.) and a frequency resource (e.g., subcarrier, frequency band, so on). When used as a frequency-domain unit, a PRB is 12 consecutive subcarriers. There are 14
 5 symbols in a slot when a normal cyclic prefix is used and 12 symbols in a slot when an extended cyclic prefix is used. The duration of a symbol is inversely proportional to the subcarrier spacing (SCS). For a $\{15, 30, 60, 120\}$ kHz SCS, the duration of a slot is $\{1, 0.5, 0.25, 0.125\}$ ms, respectively. Each PRB may be allocated to combinations of a control channel, a shared channel, a feedback channel, reference signals, and so on. In addition,
 10 some REs of a PRB may be reserved. A similar structure is likely to be used on the sidelink as well. A communication resource may be a PRB, a set of PRBs, a code (if code division multiple access (CDMA) is used, similarly as for the physical uplink control channel (PUCCH)), a physical sequence, a set of REs, and so on.

The feedback channel in the NR sidelink is used for communication of hybrid automatic
 15 repeat request (HARQ) feedback, which comprises an acknowledgment (ACK) or a negative acknowledgement (NACK) of successful receipt of a block of data in a shared channel. The amount of ACK/NACK (A/N) information is small and, therefore, the physical sidelink feedback channel (PSFCH) does not need to be configured (or transmitted) in every slot of a resource pool if the latency constraints allow it. Instead, as
 20 agreed in RAN1, a PSFCH can be configured on one every N slots in the resource pool (possibly more symbols in future releases), where N may take integer values such as 1, 2, 4, etc. Therefore, if slot n_f in the resource pool contains PSFCH resources, so do slots $n_f + N, n_f + 2N, n_f + 3N, \dots$. The notation $k \bmod N = n_f$ can be used to indicate every slot k that contains a PSFCH ‘instance’ or a PSFCH ‘opportunity.’

25 When a transmitting UE (TxUE) transmit signals (e.g. for a shared channel) to a receiving UE (RxUE), the RxUE attempts to demodulate and decode the signals. If the process (e.g. decoding) is successful, the RxUE may send an ACK to the TxUE; otherwise, the RxUE may send a NACK to the TxUE. An example of an ACK is a logical / binary “1” while a NACK is a logical / binary “0”. Whether the RxUE sends an ACK/NACK depends
 30 on the standard and the HARQ process configuration. There are generally four possible cases, shown in Table 1.

Transmit ACK	Transmit NACK	Remarks
Y	Y	Called option 2 in RAN1 agreements; useful for unicast

N	Y	Called option 1 in RAN1 agreements; useful for groupcast
Y	N	Similar to IEEE 802.11
N	N	E.g., when a HARQ process is not configured; useful for broadcast

Table 1: Possible ACK/NACK cases.

A typical operation is for the TxUE to transmit a control channel and a shared channel. The physical sidelink control channel (PSCCH) contains sidelink control information (SCI) indicating the scheduling of a shared channel, where the scheduling provides
5 information for the location (e.g. start and size) of the shared channel, the modulation-coding scheme (MCS), etc. Additional information may include fields related to the HARQ process, such as a redundancy version, a new data indicator, and a HARQ process number. Other information may include UE identifiers (UE ID) for both the source (transmitting) UE and destination (receiving) UE. If the RxUE is unable to decode the
10 control channel for a single transmission, no feedback signal may be transmitted by the RxUE. However, if a periodic or semi-persistent transmission is scheduled for a TxUE, and the RxUE fails to receive a transport block (TB), the RxUE can send a NACK to the TxUE.

Except for the last case shown in Table 1, the RxUE may need to transmit a feedback.
15 Having knowledge of n_f and N as well as other configuration parameters, the RxUE can locate PSFCH resources that can be used for transmitting the feedback. However, there is another parameter that the RxUE needs to consider. When RxUE receives the signals, the RxUE needs time to process and decode the signal, create the ACK/NACK signals, and so on. The minimum time needed between receiving the last symbol of the signal and
20 transmitting the feedback signals should be known.

It is agreed in RAN1 to have a parameter K as the minimum slot number difference between the slot containing the last symbol of a physical sidelink shared channel (PSSCH) and the slot containing its associated PSFCH.

Another parameter X can be defined as the number of PSFCH symbols in a PSFCH
25 format with a repetition of a one-symbol PSFCH. For example, when $X = 1$, A/N feedback is not repeated; but when $X = 2$, the RxUE retransmits the A/N feedback, which can improve reliability by increasing the effective signal-to-noise ratio (SNR) of the feedback signal received by the TxUE. For Rel-16, $X=1$ is supported.

Figure 4 illustrates a diagram 400 of an example PSFCH configuration with parameters N , K , and X in a RP. As shown in Figure 4, a TxUE transmits signals on PSSCH_m in slot n 405. In this example, the earliest possible slot for the corresponding A/N_m, i.e., $n + K$ (slot 407), does not contain PSFCH resources. Hence, the RxUE should wait an
 5 additional number of slots in order to transmit feedback.

In the example illustrated in Figure 4, an OFDM symbol is designated as a guard period (GP), such as GP 409, immediately preceding the PSFCH symbols 411 in order to allow UEs to switch (possibly) between transmission and reception modes. In addition, time
 10 may be needed for automatic gain control (AGC) circuitry to settle at the UE receiving the PSFCH (i.e., the TxUE). This time may be part of a GP symbol or be another symbol. Another AGC symbol, not shown in Figure 4, may be the first symbol of a slot. AGC and GP symbols, as well as other signals such as reference signals in a slot, may be omitted in figures of this disclosure unless needed. Furthermore, X is usually assumed 1 unless
 stated otherwise.

15 Figure 5 illustrates a diagram 500 of a resulting mapping of PSSCH resources to the corresponding PSFCH. As an example, N slots 505 are mapped to PSFCH 510.

Similar to the design of PUCCH formats, different PSFCH formats are possible and likely to be approved for different scenarios. The different formats can be categorized as short (e.g., 1-2 OFDM symbols) or long (e.g., longer than 4 OFDM symbols), which can be used
 20 for different SNR needs. Another possible format may include more PRBs. Also, in terms of the payload size, different formats can be defined that carry a small payload of 1 or 2 bits versus larger payloads, the latter case useful if ACK/NACK bundling will be adopted. Table 2 summarizes the NR Rel-15 PUCCH formats.

	Short PUCCH	Long PUCCH
Small Payload	Format 0	Format 1
Moderate/Large Payload	Format 2	Format 3 / Format 4

Table 2: NR Rel-15 PUCCH formats.

25 Typical PSFCH formats could be based on PUCCH format 0 and format 2, both short formats, but suitable for carrying ≤ 2 bits and > 2 bits, respectively. A PSFCH format based on PUCCH format 0 can be designed based on sequence selection, which can be utilized for application of some example embodiments in this disclosure.

Although the discussion presented herein typically focusses on short-format PSFCHs, the example embodiments are also operable with long-format PSFCHs. Therefore, the discussion of short-format PSFCHs should not be construed as being limiting to the scope of the example embodiments.

- 5 For short-format PSFCHs, the frequency resource to use is likely to be determined based on the following:
 - Information contained in the SCI.
 - RP configuration.
 - Implicit resource determination based on the resources occupied by the
- 10 PSSCH or the PSCCH.
 - Parameters exchanged between members of the unicast/groupcast link.

Figure 6 illustrates a diagram of a communications system 600 highlighting a communications situation of interest. As shown in Figure 6, UE A 605 and UE B 610 both transmit PSSCH and associated PSCCH (in a unicast mode) to UE C 615 (shown as

15 lines 620. Additionally, UE C 615 transmits HARQ feedback (shown as lines 625) on the PSFCH to UE A 605 and UE B 610.

For discussion purposes, consider a situation where UE A 605 transmits packet 1 to UE C 615, UE B 610 transmits packet 2 to UE C 615, and that UE C 615 has to transmit HARQ feedback on the PSFCH at the same time, as shown in Figure 6. In this situation, it is

20 assumed that $N = 4$ and that the both HARQ feedbacks for packet 1 and packet 2 will need to be transmitted by UE C 615 at next PSFCH occasion. Using the procedures to derive the resources used for PSFCH, it is highly likely that the PSFCHs for UE A 605 and UE B 610 are not adjacent in frequency.

Figure 7 illustrates a diagram 700 highlighting a high in-band emission (IBE) situation.

25 In the frequency resources between the two PSFCHs, there is high IBE. The high IBE arises in the area of the PSFCH that does not include an actual transmission, but emissions in the area are high due to unwanted transmitter effects such as harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, and so on. The high IBE causes problems for UEs (e.g., not the UEs shown in

30 Figure 6) that have to receive a PSFCH in this zone: the high IBE caused by the PSFCH transmissions by UE C 615 may “drown out” other PSFCHs due to the high level of interference. Therefore, there is a need for solutions to avoid having a UE transmitting two non-adjacent PSFCHs in the same time instance.

Although the problem is illustrated for PSFCHs transmitted to two different UEs (e.g., UE A 605 and UE B 610 of Figure 6). A similar problem exists for a single UE transmitting two different PSFCHs to another single UE. Therefore, the discussion of PSFCHs transmitted to two different UEs should not be construed as being limiting to the scope of the example embodiments.

In general, there are two types of problems to consider:

- Transmission of multiple PSFCHs (from UE C, for example)
 - Where should the PSFCHs be transmitted?
 - How will UE A and UE B know where to receive the PSFCH from UE C?
- If multiple feedback bits are transmitted in the same PSFCH
 - How to associate the bit to the packet transmission?

According to an example embodiment, an indication of the PSFCH location is transmitted by the device transmitting the PSFCH. As an example, the device (such as UE C 615 of Figure 6) follows the NR Rel-16 procedure for the time determination of where to send the PSFCH (the use of the K value indicated in the DCI, for example). However, the frequency location is determined by UE C 615. UE C 615 indicates the frequency location in a message sent to both UE A 605 and UE B 610.

Figure 8 illustrates a flow diagram of example operations 800 occurring at a device transmitting the PSFCH. Operations 800 may be indicative of operations occurring in a device, such as UE C 615, as the device transmits the PSFCH. For discussion purposes, the devices are identified as shown in Figure 6.

As shown in Figure 8, the device (e.g., UE C 615) receives a first SCI (in a PSCCH) from UE A 605 (block 805). The device determines the location of the PSFCH from the first SCI. The location of the PSFCH includes a time resource component and a frequency resource component, hence determining the location of the PSFCH involves determining the time resource component and the frequency resource component of the PSFCH. The time resource component is based on the last slot of the PSSCH. The PSSCH is scheduled by the first SCI and may be transmitted in multiple slots. When one slot is used for the PSSCH and when the SCI is transmitted in the same slot as the PSSCH, then the time resource component is directly associated with the SCI. The frequency resource component is determined by fields of the SCI, such as the identifier of the source (e.g., the identifier of UE A 605), the identifier of the destination (e.g., the identifier of UE C 615), a transmission type (e.g., unicast, broadcast, etc.), and a calculation based on those fields. The contents of the SCI may include the identifier of the source of the SCI (e.g., UE

A 605) and possibly the identifier of the destination (e.g., the device (UE C 615)) and a type of the transmission (e.g., a unicast, a groupcast, a broadcast, etc.).

As an example, the device decodes the PSCCH and receives the first SCI from UE A 605. The first SCI may indicate the following:

- Information indicating a packet transmission (packet 1).
- Information indicating the use of HARQ.
- Information relevant to determine the location of the PSFCH.

These operations can be similar to the one being currently standardized for NR Rel-16, for example.

- 10 The device receives a second SCI from UE B 610 (block 807). The device determines the location of the PSFCH from the second SCI. This operation may be similar to the above operation where the device receives the first SCI from UE A 605. Furthermore, the device receives and attempts to decode packet 1 and packet 2, from UE A 605 and UE B 610, respectively, which is not shown in Figure 8.
- 15 The device performs a check to determine if the PSFCHs are to be transmitted on the same time resource (block 809). As an example, the device determines where the individual PSFCHs for UE A 605 and UE B 610 would be located. If they are located in different time resources (corresponding to different times), the UE uses the NR Rel-16 procedures and transmits each PSFCH individually (block 811).
- 20 Other embodiments are possible: for instance, if the device determines that the two PSFCHs are located on the same time resource but are on adjacent RBs, there is no IBE problem, and the device can transmit both PSFCHs per the NR Rel-16 procedures.

If the two individual PSFCHs are to be transmitted in the same time resource (block 809), the device indicates the frequency resources of the PSFCHs (block 813) and the

- 25 HARQ feedbacks are multiplexed together and transmitted on a single PSFCH (referred to as a multiplexed PSFCH) (block 815). The device may signal the frequency resources of the PSFCHs (explicitly or implicitly), the location of the PSFCHs may be pre-configured, or the device does not provide information about the frequency resources and relies on the receiving devices (UE A 605 and UE B 610) to use blind detection. A detailed
30 discussion of the various embodiments is provided below.

A procedure for transmitting multiplexed PSFCHs is not defined in NR Rel-16. However, the procedure may use a format analogous to NR “PUCCH format 2”, for example. Alternatively, UE C could transmit two PSFCHs using the NR Rel-16 format but locate

these two PSFCHs on adjacent RBs so that there is no IBE problem. Alternatively, priority/dropping rules can be defined so that in the non-adjacent case only one PSFCH is transmitted, based on priority and/or the type of traffic (broadcast, unicast, groupcast).

- 5 Based on the multiplexing of the PSFCHs, a situation may arise wherein the format or the location of the PSFCH is different from what the UE (e.g., UE A 605 and UE B 610) might expect:
 - If the device multiplexes HARQ feedback, both UE A 605 and UE B 610 need to know that a different "PUCCH format" is to be expected (alternatively: the multiplexed HARQ feedback could be blindly determined using blind detection),
 - 10 furthermore at least one of UE A 605 or UE B 610 (and possibly both UE A 605 and UE B 610) need to know the multiplexed PSFCH location.
 - If the device locates both PSFCHs on adjacent RBs, at least one UE (possibly both UEs (UE A 605 and UE B 610)) need to know the new location of its
 - 15 PSFCH.

In such a case, the frequency resources of PSFCH need to be known. Knowledge regarding the frequency resources may be obtained in several ways:

- Pre-indication: the device may signal before the transmission of the HARQ feedback where the device will locate its PSFCH transmission. Alternatively, in mode 1,
- 20 the access node could indicate via DCI that PSFCH multiplexing will take place at a certain location.
- Implicit indication: based on, e.g., the UE ID or some other identifier associated with the device, the PSFCH resources can be determined. When UE A 605 or UE B 610 cannot find the PSFCH at the expected location, the UEs may search the
- 25 implicit location associated with the device. This could be viewed as a default or pre-configured or exception location.
- Another type of implicit indication relies on searching for PSFCH in an alternate pre-defined location, such as a next time slot or different subchannel in identical resources.
- 30 - SCI monitoring. The device (e.g., UE C 615) decodes and keeps track of source-destination UE ID pairs of all decoded SCI and can calculate when an issue occurs (such as a collision or a high IBE case, for example) and expect certain PSFCH dropping or multiplexing behavior. As in shown in Figure 4, the UE could detect such a case. For example, UE A 605 can transmit a first SCI and data in slot n 405 in Figure 4. The first
- 35 SCI contains a source UE ID indicating UE A 605 is the source of the data. Likewise, UE B 610 can transmit a second SCI and data in slot n 405, slot n+1, slot n+2, or slot n+3.

The second SCI has a field contains a source UE ID indicating UE B 610 is the source of the data. UE C 615 can decide which PSFCH to transmit accord to the source UE IDs that it received and drop (not transmit) the other PSFCH.

- SCI transmission (or “scheduled PSFCH”): In the slot where the device transmits the PSFCH, or in a prior slot, the device sends an SCI to indicate where the PSFCH resources are located in frequency, and possibly in time.

The SCI solution could be implemented in several ways:

- A single SCI may be sent to both UE A 605 and UE B 610.
- Two separate SCIs may be sent, one for UE A 605 and one for UE B 610.

- 10 In an embodiment, the SCI solution utilizes a standalone PSSCH.

In an embodiment, the SCI may include the following:

- Frequency resources of the PSFCH: may be an index of the RB(s) used for PSFCH, possibly along with a number of RBs if the PSFCH is mapped on more than one RB.
- 15 - The layer 1 (L1) ID(s) of the UEs to which the PSFCH applies.
- An order index for each UE: for instance, if multiple PSFCHs are code division multiplexed (CDM-ed) together, the order index may be the code index. Alternatively, if the PSFCHs are time division multiplexed (TDM-ed) together, the order index may be the time location of the PSFCH of interest to a particular UE.
- 20 The implicit indication may be based on the L1 ID of the device (e.g., the L1 ID of UE C 615). For instance, a set of resources for PSFCH could be reserved for these multiplexed PSFCH and indexed from 1 to N . The RB on which to transmit the PSFCH may be (the L1 ID of UE C 615) modulo N , for example. If no set of resources is reserved for the multiplexed PSFCHs, the procedure could be applied to the set of resources reserved for
- 25 PSFCH, although this could potentially increase the number of PSFCH collisions.

- In an embodiment, there may be additional processing required at the UE receiving the PSFCH. For example, UE A 605 and UE B 610 may look for PSFCH in multiple locations or formats, or look for a scheduled PSFCH at a different location in addition to a normal location. Such additional processing could increase power consumption and hurt
- 30 reliability (false or miss detection events, for example). It is advantageous in some cases to pre-configure or pre-indicate (via DCI in mode 1 or PC5 RRC or SCI, for example) that scheduled PSFCH operation will be used, to mitigate these effects.

It may be possible to use a formula based on a number that UE C 615 signals to UE A 605 and UE B 610. One method of signaling involves the exchange of RRC information between UEs (UE A 605 and UE C 615) and (UE B 610 and UE C 615). Another method involves using a UE ID (the UE ID of UE C 615, for example). In one example, the number that UE C 615 signals is denoted as n_{feedback} , then the following recursion can be used:

$$\begin{aligned} Y_{-1} &= n_{\text{feedback}}, \\ Y_k &= (A * Y_{k-1}) \bmod D, \\ L_k &= Y_k \bmod N_{\text{RB}} \text{ or } L_k = Y_k \bmod N_{\text{RB}}/L, \end{aligned}$$

where A is a positive integer, D is a positive integer, L_k represents the frequency location for the PSFCH in slot k , and N_{RB} is the bandwidth of the channel expressed in RBs. These formulas are somewhat similar to the formulas for the UE specific search space for PDCCH where $A = 37827$ and $D = 65537$. The later formulas can be used when multiple channels (L) are used, for example.

The recursion allows the PSFCH that UE C 615 transmits in to vary in frequency, thereby minimizing persistent interference.

An alternative approach may include sending the values of A and D , or signaling an index within a table of determined pairs (A, D), for example.

A variation may involve having an alternate PSFCH location that is based on the PSFCH location. For example, if the location of the first PSFCH location is x_1 and there are N possible locations for the PSFCH, the alternate location can be $N-1-x_1$. There are other options such as adding the value $\text{floor}(N/2)$ to the location: $[x_1 + \text{floor}(N/2)] \bmod N$. UE C 615 can select either location x_1 or $N-1-x_1$ for the transmission of the PSFCH. Likewise, UE A 605 can examine either location (x_1 or $N-1-x_1$) to receive the PSFCH. When UE C 615 has to transmit multiple PSFCH in the same symbol, UE C 615 can select the locations that minimize the IBE (or equivalently reduce the amount of maximum power reduction (MPR) used).

Continuing with the example, the location of the PSFCH for UE B 610 is x_2 . When UE C 615 is selecting the resources for transmission of the two PSFCHs (to UE A 605 and to UE B 610), there are four combinations to select: (x_1, x_2) , $(x_1, N-1-x_2)$, $(N-1-x_1, x_2)$ and $(N-1-x_1, N-1-x_2)$. The selection may be based on the minimum difference in location: $\min((\max \text{ RB location of combination}(i) - \min \text{ RB location of a combination}(i)))$. For instance, if $N=50$, $x_1=5$, and $x_2=30$, the combinations are $(5, 30)$, $(5, 19)$, $(44, 30)$, $(44, 19)$. $\min((30-5), (19-5), (44-30), (44-19))$. The smallest difference of 14 corresponds to two combinations $(44, 30)$ and $(5, 19)$. This procedure can be extended to 3 or more

feedbacks. If the third PSFCH location is x_3 , then there are eight combinations to examine: (x_1, x_2, x_3) , $(x_1, N-1-x_2, x_3)$, $(N-1-x_1, x_2, x_3)$, $(N-1-x_1, N-1-x_2, x_3)$, $(x_1, x_2, N-1-x_3)$, $(x_1, N-1-x_2, N-1-x_3)$, $(N-1-x_1, x_2, N-1-x_3)$ and $(N-1-x_1, N-1-x_2, N-1-x_3)$. If $x_3=15$, then the combinations are (5, 30, 15), (5, 19, 15), (44, 30, 15), (44, 19, 15), (5, 30, 34), (5, 19, 34), (44, 30, 34), (44, 19, 34). $\min((\max \text{ RB location of combination(i)} - \min \text{ RB location of a combination(i))) = \min((30-5), (19-5), (44-15), (44-15), (34-5), (34-5), (44-30), (44-19)) = 14$. In such a situation either (5, 19, 15) or (44, 30, 34) could be considered.

Figure 9 illustrates a flow diagram of example operations 900 occurring at a device receiving the PSFCH when multiplexed PSFCHs are indicated in a SCI. Operations 900 may be indicative of operations occurring at a device, such as UE A 605 or UE B 610, as the device receives the PSFCH when multiplexed PSFCHs are indicated in a SCI.

Operations 900 begin with the device sending a SCI to UE C 615 (block 905). The SCI may indicate the location of the multiplexed PSFCHs. The SCI may be sent in a PSCCH, for example. The SCI indicates the following:

- Information indicating a packet transmission (packet 1).
- Information indicating the use of HARQ.
- Information relevant to determine the location of the PSFCH.

These operations can be similar to the one being currently standardized for NR Rel-16, for example.

The device monitors the PSSCH search space (block 907). The monitoring of the PSSCH search space enables the device to receive sidelink transmissions including an indicator of resource(s) for multiplexed PSFCHs, for example. The device performs a check to determine if an indication of resource(s) for multiplexed PSFCHs has been received (block 909). If an indication has not been received, the device monitors resources on a per PSSCH or PSCCH transmission basis (block 911). If an indication has been received, the device monitors resources as indicated (block 913).

Figure 10 illustrates a flow diagram of example operations 1000 occurring at a device receiving the PSFCH when frequency resources of the multiplexed PSFCH are pre-configured. Operations 1000 may be indicative of operations occurring at a device, such as UE A 605 or UE B 610, as the device receives the PSFCH when frequency resources of the multiplexed PSFCHs are pre-configured.

Operations 1000 begin with the device sending a SCI to UE C 615 (block 1005). The SCI may indicate the location of the multiplexed PSFCHs. The SCI may be sent in a PSCCH, for example. The device attempts to obtain the multiplexed PSFCHs at the location

derived from the SCI (block 1007). In other words, the device attempts to detect the multiplexed PSFCHs at the location of the multiplexed PSFCHs, as indicated by the SCI. If the multiplexed PSFCHs were detected at the location derived from the SCI (block 1009), the device processes the PSFCH (block 1011). However, if the multiplexed PSFCHs were not detected at the location derived from the SCI, the device obtains the multiplexed PSFCHs at the pre-configured location (block 1013). As an example, the pre-configured location is in accordance with an identifier associated with UE C 615, e.g., UE ID of UE C 615 or the L1 ID of UE C 615.

According to an example embodiment, a sequence is used to scramble the PSFCH, and an indication of the sequence used to scramble the PSFCH is transmitted. As an example, the device (such as UE C 615 of Figure 6, for example) scrambles the multiplexed PSFCH and transmits the scrambled PSFCH at a location potentially unknown to UE A 605 and UE B 610. However, the scrambled PSFCH is scrambled using a scrambling sequence associated with a particular recipient, e.g., UE A 605, so that UE A 605 can assess that this scrambled PSFCH is intended for UE A 605. Similarly, UE B 610 can ascertain that the scrambled PSFCH is not intended for UE B 610 because the scrambled PSFCH is scrambled using a scrambling sequence not associated with UE B 610. The scrambling of the PSFCH may also be combined with the transmission of the indication of the PSFCH location, as discussed previously.

Figure 11 illustrates a flow diagram of example operations 1100 occurring at a device transmitting a scrambled PSFCH. Operations 1100 may be indicative of operations occurring in a device, such as UE C 615, as the device transmits a scrambled PSFCH.

Operations 1100 begin with the device receiving a first SCI (in a PSCCH) from UE A 605 (block 1105). As an example, UE C 615 decodes the PSCCH and receives an SCI from UE A 605. The device determines the location of the PSFCH from the first SCI. The device receives a second SCI from UE B 610 (block 1107). The device determines the location of the PSFCH from the second SCI. This operation may be similar to the above operation where the device receives the first SCI from UE A 605. Furthermore, the device receives and attempts to decode packet 1 and packet 2, which is not shown in Figure 11.

The device performs a check to determine if the PSFCHs are to be transmitted on same time resource (block 1109). As an example, the device determines where the individual PSFCH for UE A 605 and UE B 610 would be located. If they are located in different time resources, the UE uses the NR Rel-16 procedures and transmits each PSFCH individually (block 1111).

If the two individual PSFCHs are to be transmitted in the same time resource (block 1109), the device scrambles the multiplexed PSFCH using a scrambling sequence associated with one of the UEs (e.g., UE A 605 or UE B 610) and transmits the scrambled PSFCH (block 1113). In an embodiment, the scrambling sequence used to scramble the multiplexed PSFCH may be selected in accordance with a selection criteria or rule, such as UE priority, UE service history, priority of message being acknowledged, type of acknowledgement (e.g., NACK may have higher priority than ACK, or vice versa), traffic priority, and so on.

The scrambling of the multiplexed PSFCH may be performed in a variety of ways. As an example, the scrambling sequence may be defined in accordance with an identifier associated with UE A 605 (e.g., the UE ID of UE A 605) and the multiplexed PSFCH is scrambled using the scrambling sequence. As another example, UE A 605 indicates the scrambling sequence in the SCI sent to UE C 615 and UE C 615 uses the indicated scrambling sequence to scramble the multiplexed PSFCH. In the situation where the PSFCH are scrambled with a scrambling sequence associated with UE B 610, the scrambling sequence may be defined in accordance with an identifier associated with UE B 610 or UE B 610 may indicate which scrambling sequence to use in the SCI, for example.

Figure 12 illustrates a flow diagram of example operations 1200 occurring at a device receiving the scrambled PSFCH. Operations 1200 may be indicative of operations occurring at a device, such as UE A 605 or UE B 610, as the device receives the scrambled PSFCH.

The device sends an SCI to UE C 615 (1205). The SCI may indicate the location of the scrambled PSFCHs. The SCI may be sent in a PSCCH, for example. The device attempts to obtain the scrambled PSFCHs at the location derived from the SCI (block 1207). In other words, the device attempts to detect the scrambled PSFCHs at the location of the scrambled PSFCHs, as indicated by the SCI. The location may be a resource that the PSFCH would occupy if the PSFCH location was the location in the situation when UE C 615 only has one feedback for UE A 605, for example.

The device performs a check to determine if the device was able to successfully obtain the PSFCH (block 1209). If the device was able to successfully obtain the PSFCH, the device processes the PSFCH (block 1211).

If the device was unable to obtain the PSFCH, the device attempts to perform blind decoding or detection at all possible multiplexed PSFCH locations (block 1213). In other

words, the device performs blind detection at all possible multiplexed PSFCH locations in an attempt to obtain the multiplexed PSFCH.

The device performs a check to determine if it was able to obtain a scrambled PSFCH scrambled with a scrambling sequence associated with the device (UE A 605 in this example, but may be different for other devices) (block 1215). If the device was able to obtain a scrambled PSFCH scrambled with a scrambling sequence associated with the device, the device processes the PSFCH (block 1217). However, if the device was unable to detect a PSFCH scrambled with a scrambling sequence associated with the device, the device continues blind detection (block 1219). The device may continue by performing blind detection in locations, including locations not assigned to multiplexed PSFCHs, for example.

According to an example embodiment, an indication of duplication (i.e., redundancy) is transmitted with a multiplexed PSFCH. As described previously, the scenario of multiple PSFCHs HARQ transmissions are needed for (a) when transmitting to two or multiple UEs, or (b) when transmitting multiple HARQ transmissions to the same UE. The indication of duplication may be a single-bit or multi-bit indication. In the situation of a single-bit indication, setting the indication to a first value may indicate that duplication is occurring, and setting the indication to a second value may indicate that duplication is not occurring. Alternatively, the indication may not be transmitted at all if duplication is not occurring.

If the two individual PSFCHs are to be transmitted in the same time resource, new procedures are defined. The HARQ feedbacks are multiplexed together and transmitted on a single PSFCH (referred to as multiplexed PSFCH). This example embodiment further adds that the UE has an option to send duplication feedback in the respective channel also.

Figure 13A illustrates a diagram 1300 of PSFCH duplication with multiplexing. As shown in Figure 13A, PSFCH 1305 includes a CDM'ed HARQ feedback for UE A 605 and UE B 610, while PSFCH 1310 includes HARQ feedback for UE B 610. Figure 13B illustrates a diagram 1350 of PSFCH duplication with unicasts and groupcasts. As shown in Figure 13B, PSFCH 1355 includes a CDM'ed HARQ unicast feedback for UE A 605 and a HARQ groupcast feedback for UE B 610, while PSFCH 1360 includes HARQ groupcast feedback for UE A 605.

Furthermore, for the case (b) when UE A has multiple HARQ feedbacks for different modes, such as unicast and groupcast, for example. UE C 615 may have the option of

multiplexing the feedbacks in a single multiplexed PSFCH as well as sending the feedback in independent PSFCHs.

In order to indicate the PSFCH resource location with PSFCH duplication, the techniques previously presented for sending an indication of the PSFCH location by the device
5 transmitting the PSFCH may be utilized, along with additional information related to the PSFCH duplication. The additional information related to the PSFCH duplication may be multiplexed (or not) with the PSFCH location information.

According to an example embodiment, an indication of the PSFCH location is transmitted by the device transmitting the PSFCH, along with an indication of the
10 scrambling sequence used to scramble the multiplexed PSFCH. In an embodiment, the location of the multiplexed PSFCH is based on the identifier associated with the device (e.g., UE C 615) sending the multiplexed PSFCH. Additionally, how to find the relevant information at the multiplexed PSFCH may be based on the identifier associated with the UE that is expecting the multiplexed PSFCH (i.e., UE A 605 or UE B 610). The
15 information is implicitly based on the identifiers associated with the involved UEs, hence additional signaling is not required, for example.

Figure 14 illustrates a flow diagram of example operations 1400 occurring at a device transmitting the PSFCH, where an indication of the PSFCH location is transmitted by the device transmitting the PSFCH, along with an indication of the scrambling sequence
20 used to scramble the multiplexed PSFCH. Operations 1400 may be indicative of operations occurring at a device (i.e., UE C 615) as the device transmits the PSFCH, along with the indication of the PSFCH location and scrambling sequence.

The device receives a first SCI (in a PSCCH) from UE A 605 (block 1405). As an example, the device decodes the PSCCH and receives the first SCI from UE A 605. The device
25 determines the location of the PSFCH from the first SCI. The device receives a second SCI from UE B 610 (block 1407). The device determines the location of the PSFCH from the second SCI. This operation may be similar to the above operation where the device receives the first SCI from UE A 605. Furthermore, the device receives and attempts to decode packet 1 and packet 2, from UE A 605 and UE B 610, respectively, which is not
30 shown in Figure 14.

The device performs a check to determine if the PSFCHs are to be transmitted on the same time resource (block 1409). As an example, the device determines where the individual PSFCHs for UE A 605 and UE B 610 would be located. If they are located in

different time resources, the UE uses the NR Rel-16 procedures and transmits each PSFCH individually (block 1411).

The device determines the location of the multiplexed PSFCH (block 1413). The location of the multiplexed PSFCH may be determined in accordance with the identifier (e.g., UE ID) of UE C 615, for example. The device also scrambles the PSFCH associated with UE A 605 with a scrambling sequence associated with UE A 605, e.g., a UE A specific code (block 1415) and scrambles the PSFCH associated with UE B 610 with a scrambling sequence associated with UE B 610, e.g., a UE B specific code (block 1417). The device transmits the multiplexed and scrambled PSFCH (block 1419).

Figure 15 illustrates a flow diagram of example operations 1500 occurring at a device receiving the multiplexed PSFCH, where an indication of the PSFCH location and an indication of the scrambling sequence used to scramble the PSFCH are also received by the device. Operations 1500 may be indicative of operations occurring in a device (such as UE A 605 or UE B 610) as the device receives the multiplexed PSFCH, along with an indication of the PSFCH location and an indication of the scrambling sequence.

The device sends an SCI to UE C 615 (1505). The SCI may indicate the location of the scrambled PSFCHs. The SCI may be sent in a PSCCH, for example. The device attempts to obtain the scrambled PSFCHs at the location derived from the SCI (block 1507). In other words, the device attempts to detect the scrambled PSFCHs at the location of the scrambled PSFCHs, as indicated by the SCI. The location may be a resource that the PSFCH would occupy if the PSFCH location was the location in the situation when UE C 615 only has one feedback for UE A 605, for example.

The device performs a check to determine if the device was able to successfully obtain the PSFCH (block 1509). If the device was able to successfully obtain the PSFCH, the device processes the PSFCH (block 1511).

If the device was unable to obtain the PSFCH, the device determines the location of the multiplexed PSFCH (block 1513). The location of the multiplexed PSFCH may be determined in accordance with the identifier of UE C 615, for example. The device receives the multiplexed PSFCH at the location (block 1515). As an example, the device receives the multiplexed PSFCH at the location determined in accordance with the identifier of UE C 615. The device also applies a scrambling code associated with the device (e.g., UE A 605 or UE B 610) based on the identifier of the device, for example. The device also processes the PSFCH.

Figure 16 illustrates an example communication system 1600. In general, the system 1600 enables multiple wireless or wired users to transmit and receive data and other content. The system 1600 may implement one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency
5 division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), or non-orthogonal multiple access (NOMA).

In this example, the communication system 1600 includes electronic devices (ED) 1610a-1610c, radio access networks (RANs) 1620a-1620b, a core network 1630, a public switched telephone network (PSTN) 1640, the Internet 1650, and other networks 1660.

10 While certain numbers of these components or elements are shown in Figure 16, any number of these components or elements may be included in the system 1600.

The EDs 1610a-1610c are configured to operate or communicate in the system 1600. For example, the EDs 1610a-1610c are configured to transmit or receive via wireless or wired communication channels. Each ED 1610a-1610c represents any suitable end user device
15 and may include such devices (or may be referred to) as a user equipment or device (UE), wireless transmit or receive unit (WTRU), mobile station, fixed or mobile subscriber unit, cellular telephone, personal digital assistant (PDA), smartphone, laptop, computer, touchpad, wireless sensor, or consumer electronics device.

The RANs 1620a-1620b here include base stations 1670a-1670b, respectively. Each base
20 station 1670a-1670b is configured to wirelessly interface with one or more of the EDs 1610a-1610c to enable access to the core network 1630, the PSTN 1640, the Internet 1650, or the other networks 1660. For example, the base stations 1670a-1670b may include (or be) one or more of several well-known devices, such as a base transceiver station (BTS), a Node-B (NodeB), an evolved NodeB (eNodeB), a Next Generation (NG)
25 NodeB (gNB), a Home NodeB, a Home eNodeB, a site controller, an access point (AP), or a wireless router. The EDs 1610a-1610c are configured to interface and communicate with the Internet 1650 and may access the core network 1630, the PSTN 1640, or the other networks 1660.

In the embodiment shown in Figure 16, the base station 1670a forms part of the RAN
30 1620a, which may include other base stations, elements, or devices. Also, the base station 1670b forms part of the RAN 1620b, which may include other base stations, elements, or devices. Each base station 1670a-1670b operates to transmit or receive wireless signals within a particular geographic region or area, sometimes referred to as a “cell.” In some embodiments, multiple-input multiple-output (MIMO) technology may be employed
35 having multiple transceivers for each cell.

The base stations 1670a-1670b communicate with one or more of the EDs 1610a-1610c over one or more air interfaces 1690 using wireless communication links. The air interfaces 1690 may utilize any suitable radio access technology.

It is contemplated that the system 1600 may use multiple channel access functionality, including such schemes as described above. In particular embodiments, the base stations and EDs implement 5G New Radio (NR), LTE, LTE-A, or LTE-B. Of course, other multiple access schemes and wireless protocols may be utilized.

The RANs 1620a-1620b are in communication with the core network 1630 to provide the EDs 1610a-1610c with voice, data, application, Voice over Internet Protocol (VoIP), or other services. Understandably, the RANs 1620a-1620b or the core network 1630 may be in direct or indirect communication with one or more other RANs (not shown). The core network 1630 may also serve as a gateway access for other networks (such as the PSTN 1640, the Internet 1650, and the other networks 1660). In addition, some or all of the EDs 1610a-1610c may include functionality for communicating with different wireless networks over different wireless links using different wireless technologies or protocols. Instead of wireless communication (or in addition thereto), the EDs may communicate via wired communication channels to a service provider or switch (not shown), and to the Internet 1650.

Although Figure 16 illustrates one example of a communication system, various changes may be made to Figure 16. For example, the communication system 1600 could include any number of EDs, base stations, networks, or other components in any suitable configuration.

Figures 17A and 17B illustrate example devices that may implement the methods and teachings according to this disclosure. In particular, Figure 17A illustrates an example ED 1710, and Figure 17B illustrates an example base station 1770. These components could be used in the system 1600 or in any other suitable system.

As shown in Figure 17A, the ED 1710 includes at least one processing unit 1700. The processing unit 1700 implements various processing operations of the ED 1710. For example, the processing unit 1700 could perform signal coding, data processing, power control, input/output processing, or any other functionality enabling the ED 1710 to operate in the system 1600. The processing unit 1700 also supports the methods and teachings described in more detail above. Each processing unit 1700 includes any suitable processing or computing device configured to perform one or more operations. Each processing unit 1700 could, for example, include a microprocessor, microcontroller,

digital signal processor, field programmable gate array, or application specific integrated circuit.

The ED 1710 also includes at least one transceiver 1702. The transceiver 1702 is configured to modulate data or other content for transmission by at least one antenna or
5 NIC (Network Interface Controller) 1704. The transceiver 1702 is also configured to demodulate data or other content received by the at least one antenna 1704. Each transceiver 1702 includes any suitable structure for generating signals for wireless or wired transmission or processing signals received wirelessly or by wire. Each antenna 1704 includes any suitable structure for transmitting or receiving wireless or wired
10 signals. One or multiple transceivers 1702 could be used in the ED 1710, and one or multiple antennas 1704 could be used in the ED 1710. Although shown as a single functional unit, a transceiver 1702 could also be implemented using at least one transmitter and at least one separate receiver.

The ED 1710 further includes one or more input/output devices 1706 or interfaces (such
15 as a wired interface to the Internet 1650). The input/output devices 1706 facilitate interaction with a user or other devices (network communications) in the network. Each input/output device 1706 includes any suitable structure for providing information to or receiving information from a user, such as a speaker, microphone, keypad, keyboard, display, or touch screen, including network interface communications.

20 In addition, the ED 1710 includes at least one memory 1708. The memory 1708 stores instructions and data used, generated, or collected by the ED 1710. For example, the memory 1708 could store software or firmware instructions executed by the processing unit(s) 1700 and data used to reduce or eliminate interference in incoming signals. Each memory 1708 includes any suitable volatile or non-volatile storage and retrieval
25 device(s). Any suitable type of memory may be used, such as random access memory (RAM), read only memory (ROM), hard disk, optical disc, subscriber identity module (SIM) card, memory stick, secure digital (SD) memory card, and the like.

As shown in Figure 17B, the base station 1770 includes at least one processing unit 1750, at least one transceiver 1752, which includes functionality for a transmitter and a
30 receiver, one or more antennas 1756, at least one memory 1758, and one or more input/output devices or interfaces 1766. A scheduler, which would be understood by one skilled in the art, is coupled to the processing unit 1750. The scheduler could be included within or operated separately from the base station 1770. The processing unit 1750 implements various processing operations of the base station 1770, such as signal coding,
35 data processing, power control, input/output processing, or any other functionality. The

processing unit 1750 can also support the methods and teachings described in more detail above. Each processing unit 1750 includes any suitable processing or computing device configured to perform one or more operations. Each processing unit 1750 could, for example, include a microprocessor, microcontroller, digital signal processor, field programmable gate array, or application specific integrated circuit.

Each transceiver 1752 includes any suitable structure for generating signals for wireless or wired transmission to one or more EDs or other devices. Each transceiver 1752 further includes any suitable structure for processing signals received wirelessly or by wire from one or more EDs or other devices. Although shown combined as a transceiver 1752, a transmitter and a receiver could be separate components. Each antenna 1756 includes any suitable structure for transmitting or receiving wireless or wired signals. While a common antenna 1756 is shown here as being coupled to the transceiver 1752, one or more antennas 1756 could be coupled to the transceiver(s) 1752, allowing separate antennas 1756 to be coupled to the transmitter and the receiver if equipped as separate components. Each memory 1758 includes any suitable volatile or non-volatile storage and retrieval device(s). Each input/output device 1766 facilitates interaction with a user or other devices (network communications) in the network. Each input/output device 1766 includes any suitable structure for providing information to or receiving/providing information from a user, including network interface communications.

Figure 18 is a block diagram of a computing system 1800 that may be used for implementing the devices and methods disclosed herein. For example, the computing system can be any entity of UE, access network (AN), mobility management (MM), session management (SM), user plane gateway (UPGW), or access stratum (AS). Specific devices may utilize all of the components shown or only a subset of the components, and levels of integration may vary from device to device. Furthermore, a device may contain multiple instances of a component, such as multiple processing units, processors, memories, transmitters, receivers, etc. The computing system 1800 includes a processing unit 1802. The processing unit includes a central processing unit (CPU) 1814, memory 1808, and may further include a mass storage device 1804, a video adapter 1810, and an I/O interface 1812 connected to a bus 1820.

The bus 1820 may be one or more of any type of several bus architectures including a memory bus or memory controller, a peripheral bus, or a video bus. The CPU 1814 may comprise any type of electronic data processor. The memory 1808 may comprise any type of non-transitory system memory such as static random access memory (SRAM), dynamic random access memory (DRAM), synchronous DRAM (SDRAM), read-only

memory (ROM), or a combination thereof. In an embodiment, the memory 1808 may include ROM for use at boot-up, and DRAM for program and data storage for use while executing programs.

5 The mass storage 1804 may comprise any type of non-transitory storage device configured to store data, programs, and other information and to make the data, programs, and other information accessible via the bus 1820. The mass storage 1804 may comprise, for example, one or more of a solid state drive, hard disk drive, a magnetic disk drive, or an optical disk drive.

10 The video adapter 1810 and the I/O interface 1812 provide interfaces to couple external input and output devices to the processing unit 1802. As illustrated, examples of input and output devices include a display 1818 coupled to the video adapter 1810 and a mouse, keyboard, or printer 1816 coupled to the I/O interface 1812. Other devices may be coupled to the processing unit 1802, and additional or fewer interface cards may be utilized. For example, a serial interface such as Universal Serial Bus (USB) (not shown)
15 may be used to provide an interface for an external device.

The processing unit 1802 also includes one or more network interfaces 1806, which may comprise wired links, such as an Ethernet cable, or wireless links to access nodes or different networks. The network interfaces 1806 allow the processing unit 1802 to communicate with remote units via the networks. For example, the network interfaces
20 1806 may provide wireless communication via one or more transmitters/transmit antennas and one or more receivers/receive antennas. In an embodiment, the processing unit 1802 is coupled to a local-area network 1822 or a wide-area network for data processing and communications with remote devices, such as other processing units, the Internet, or remote storage facilities.

25 It should be appreciated that one or more steps of the embodiment methods provided herein may be performed by corresponding units or modules. For example, a signal may be transmitted by a transmitting unit or a transmitting module. A signal may be received by a receiving unit or a receiving module. A signal may be processed by a processing unit or a processing module. Other steps may be performed by a determining unit or module,
30 a multiplexing unit or module, a scrambling unit or module, or an indicating unit or module. The respective units or modules may be hardware, software, or a combination thereof. For instance, one or more of the units or modules may be an integrated circuit, such as field programmable gate arrays (FPGAs) or application-specific integrated circuits (ASICs).

Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the scope of the disclosure as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method implemented by a first user equipment (UE), the method comprising:
determining, by the first UE, a first sidelink feedback resource in accordance with
a first sidelink transmission received from a second UE, the first sidelink feedback
5 resource comprising a first frequency resource and a first time resource, the first sidelink
feedback resource being associated with a transmission of a first sidelink feedback
message responsive to the first sidelink transmission;
determining, by the first UE, a second sidelink feedback resource in accordance
with a second sidelink transmission received from a third UE, the second sidelink
10 feedback resource comprising a second frequency resource and the first time resource,
the second sidelink feedback resource being associated with a transmission of a second
sidelink feedback message responsive to the second sidelink transmission;
multiplexing, by the first UE, the first sidelink feedback message and the second
sidelink feedback message; and
15 transmitting, by the first UE, the multiplexed first and second sidelink feedback
messages in a third frequency resource.
2. The method of claim 1, further comprising:
scrambling, by the first UE, the first sidelink feedback message with a first
scrambling code associated with the second UE; and
20 scrambling, by the first UE, the second sidelink feedback message with a second
scrambling code associated with the third UE,
the scrambling occurring before the multiplexing.
3. The method of claim 2, the first scrambling code being associated with an
identifier of the second UE, and the second scrambling code being associated with an
25 identifier of the third UE.
4. The method of any one of claim 1-3, the multiplexed first and second sidelink
feedback messages being transmitted in the third frequency resource of the first time
resource.
5. The method of any one of claims 1-3, further comprising transmitting, by the first
30 UE, a message including an indication of the third frequency resource used to transmit
the first sidelink feedback message and the second sidelink feedback message.
6. The method of claim 5, the message further comprising an indication of a second
time resource, and the multiplexed first and second sidelink feedback messages being
transmitting in the third frequency resource of the second time resource.

7. The method of claim 5, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of a third time resource, the third time resource being associated with the transmission of the message.
8. The method of any one of claims 1-7, determining the first sidelink feedback resource comprising receiving a first sidelink control information (SCI) message including an indication of the first sidelink feedback resource, and determining the second sidelink feedback resource comprising receiving a second SCI message including an indication of the second sidelink feedback resource.
9. The method of any one of claims 1-8, further comprising:
- 10 determining, by the first UE, a third sidelink feedback resource in accordance with a third sidelink transmission received from a fourth UE, the third sidelink feedback resource comprising a fourth frequency resource and a fourth time resource, the third sidelink feedback resource being associated with a transmission of a third sidelink feedback message responsive to the third sidelink transmission; and
- 15 determining, by the first UE, that the first time resource and the fourth time resource are different time resources, and based thereon:
- transmitting, by the first UE, the third sidelink feedback message in the fourth frequency resource of the fourth time resource.
10. A method implemented by a first user equipment (UE), the method comprising:
- 20 receiving, by the first UE from a second UE, a first indicator of a first sidelink feedback resource associated with a transmission of a first sidelink feedback message responsive to a sidelink transmission received from the second UE, the first sidelink feedback resource comprising a first frequency resource and a first time resource;
- receiving, by the first UE from a third UE, a second indicator of a second sidelink feedback resource associated with a transmission of a second sidelink feedback message responsive to a sidelink transmission received from the third UE, the second sidelink feedback resource comprising a second frequency resource and a second time resource;
- 25 and
- determining, by the first UE, that the first time resource and the second time resource are the same, and based thereon:
- 30 determining, by the first UE, a frequency resource in accordance with an identifier of the first UE;
- multiplexing, by the first UE, the first sidelink feedback message and the second sidelink feedback message; and

transmitting, by the first UE, the multiplexed first and second sidelink feedback messages in the frequency resource.

11. The method of claim 10, further comprising:
scrambling, by the first UE, the first sidelink feedback message with a first
5 scrambling code associated with the second UE; and
scrambling, by the first UE, the second sidelink feedback message with a second
scrambling code associated with the third UE,
the scrambling occurring before the multiplexing.
12. The method of claim 11, the first scrambling code being associated with an
10 identifier of the second UE, and the second scrambling code being associated with an
identifier of the third UE.
13. The method of any one of claims 10-12, the first indicator being received in a first
sidelink control information (SCI) message, and the second indicator being received in a
second SCI message.
14. The method of any one of claims 10-13, the multiplexed first and second sidelink
15 feedback messages being transmitted in the frequency resource of the first time resource.
15. A first user equipment (UE) comprising:
one or more processors; and
a non-transitory memory storage comprising instructions that, when executed by
20 the one or more processors, cause the first UE to:
determine a first sidelink feedback resource in accordance with a first
sidelink transmission received from a second UE, the first sidelink feedback resource
comprising a first frequency resource and a first time resource, the first sidelink feedback
resource being associated with a transmission of a first sidelink feedback message
25 responsive to the first sidelink transmission;
determine a second sidelink feedback resource in accordance with a
second sidelink transmission received from a third UE, the second sidelink feedback
resource comprising a second frequency resource and the first time resource, the second
sidelink feedback resource being associated with a transmission of a second sidelink
30 feedback message responsive to the second sidelink transmission;
multiplex the first sidelink feedback message and the second sidelink
feedback message; and
transmit the multiplexed first and second sidelink feedback messages in a
third frequency resource.

16. The first UE of claim 15, the instructions further causing the first UE to scramble the first sidelink feedback message with a first scrambling code associated with the second UE; and scramble, by the first UE, the second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before
5 multiplexing the first sidelink feedback message and the second sidelink feedback message.

17. The first UE of claim 16, the first scrambling code being associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

10 18. The first UE of any one of claims 15-17, the multiplexed first and second sidelink feedback messages being transmitted in the third frequency resource of the first time resource.

19. The first UE of any one of claims 15-17, the instructions further causing the first UE to transmit a message including an indication of the third frequency resource used to
15 transmit the first sidelink feedback message and the second sidelink feedback message.

20. The first UE of claim 19, the message further comprising an indication of a second time resource, and the multiplexed first and second sidelink feedback messages being transmitting in the third frequency resource of the second time resource.

21. The first UE of claim 19, the multiplexed first and second sidelink feedback
20 messages being transmitted in the third frequency resource of a third time resource, the third time resource being associated with the transmission of the message.

22. The first UE of any one of claims 15-21, the instructions further causing the first UE to receive a first sidelink control information (SCI) message including an indication of the first sidelink feedback resource and to receive a second SCI message including an
25 indication of the second sidelink feedback resource.

23. The first UE of any one of claims 15-22, the instructions further causing the first UE to determine a third sidelink feedback resource in accordance with a third sidelink transmission received from a fourth UE, the third sidelink feedback resource comprising a fourth frequency resource and a fourth time resource, the third sidelink feedback
30 resource being associated with a transmission of a third sidelink feedback message responsive to the third sidelink transmission; and determine that the first time resource and the fourth time resource are different time resources, and based thereon: transmit

the third sidelink feedback message in the fourth frequency resource of the fourth time resource.

24. A first user equipment (UE) comprising:

one or more processors; and

5 a non-transitory memory storage comprising instructions that, when executed by the one or more processors, cause the first UE to:

receive, from a second UE, a first indicator of a first sidelink feedback resource associated with a transmission of a first sidelink feedback message responsive to a sidelink transmission received from the second UE, the first sidelink feedback resource
10 comprising a first frequency resource and a first time resource;

receive, from a third UE, a second indicator of a second sidelink feedback resource associated with a transmission of a second sidelink feedback message responsive to a sidelink transmission received from the third UE, the second sidelink feedback resource comprising a second frequency resource and a second time resource;
15 and

determine that the first time resource and the second time resource are the same, and based thereon:

determine a frequency resource in accordance with an identifier of the first UE;

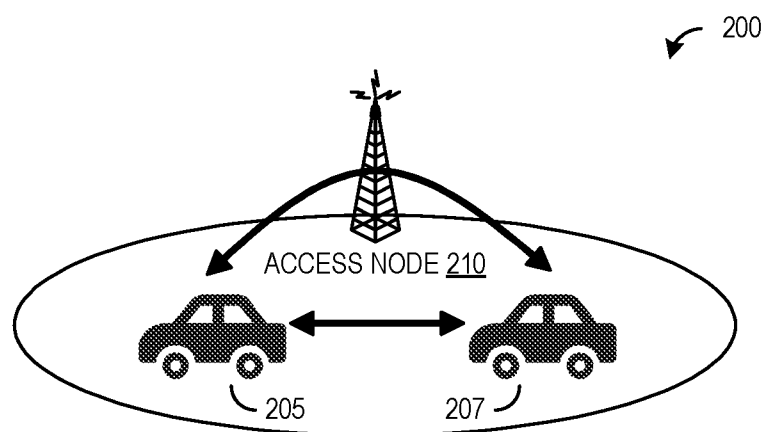
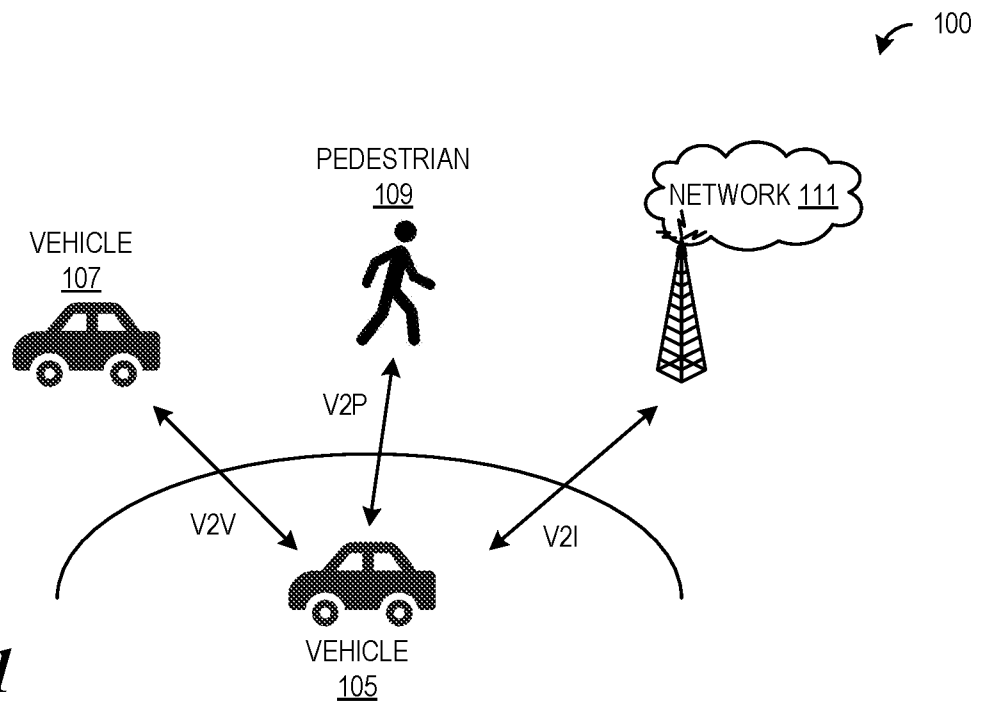
20 multiplex the first sidelink feedback message and the second sidelink feedback message; and

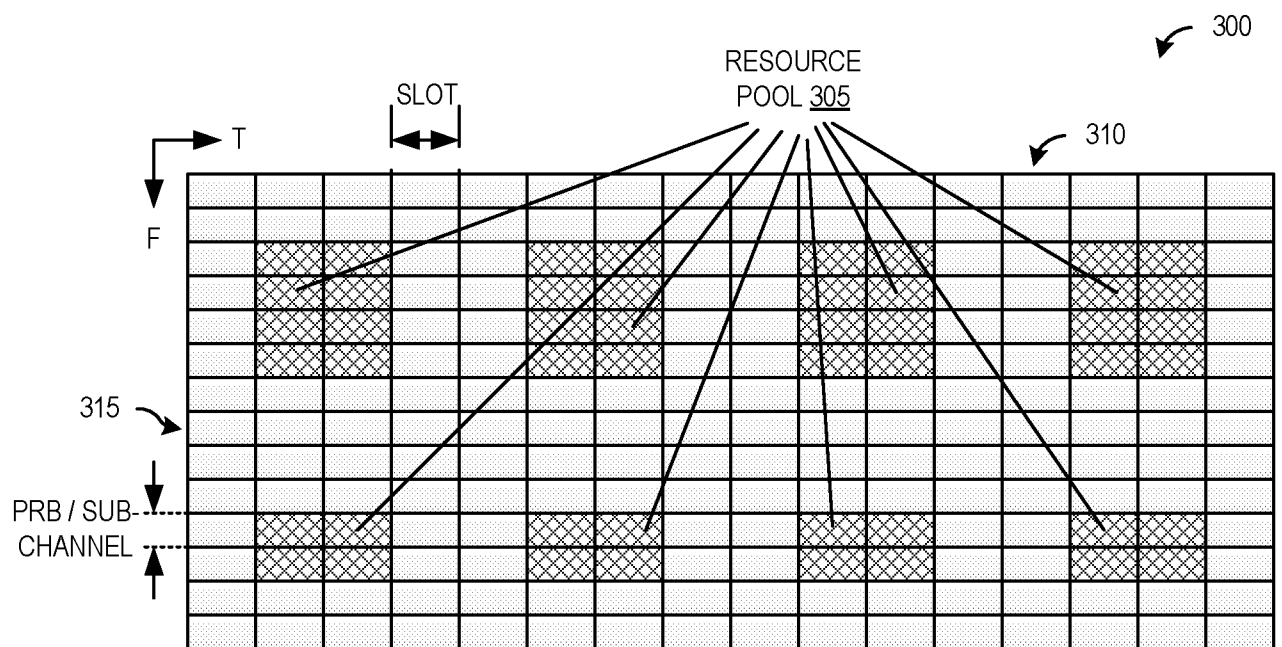
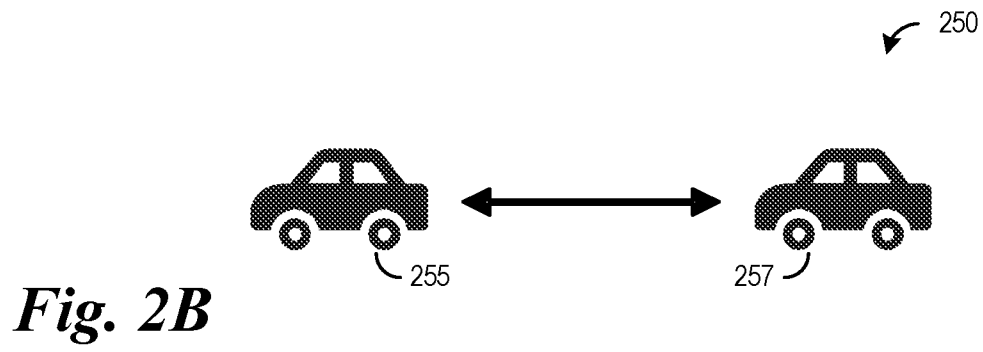
transmit the multiplexed first and second sidelink feedback messages in the frequency resource.

25 25. The first UE of claim 24, the instructions further causing the first UE to scramble the first sidelink feedback message with a first scrambling code associated with the second UE; and scramble the second sidelink feedback message with a second scrambling code associated with the third UE, the scrambling occurring before multiplexing the first sidelink feedback message and the second sidelink feedback message.

30 26. The first UE of claim 25, the first scrambling code being associated with an identifier of the second UE, and the second scrambling code being associated with an identifier of the third UE.

27. The first UE of any one of claims 24-26, the first indicator being received in a first sidelink control information (SCI) message, and the second indicator being received in a second SCI message.
28. The first UE of any one of claims 24-27, the multiplexed first and second sidelink
5 feedback messages being transmitted in the frequency resource of the first time resource.





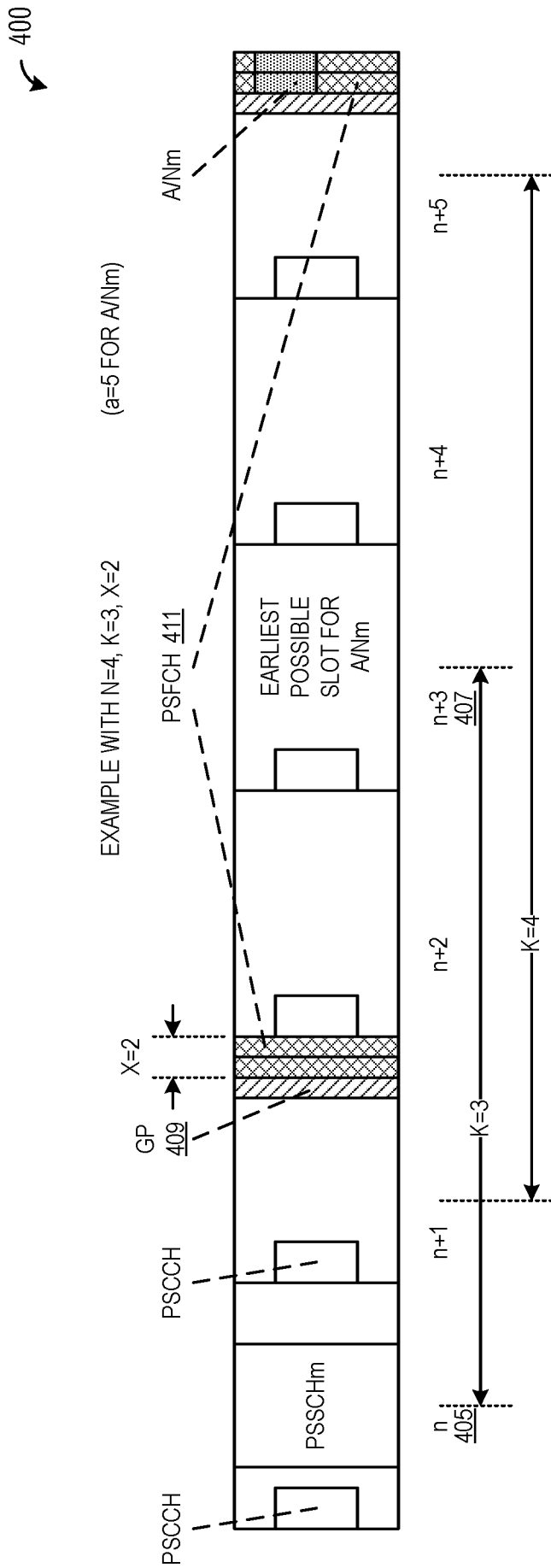


Fig. 4

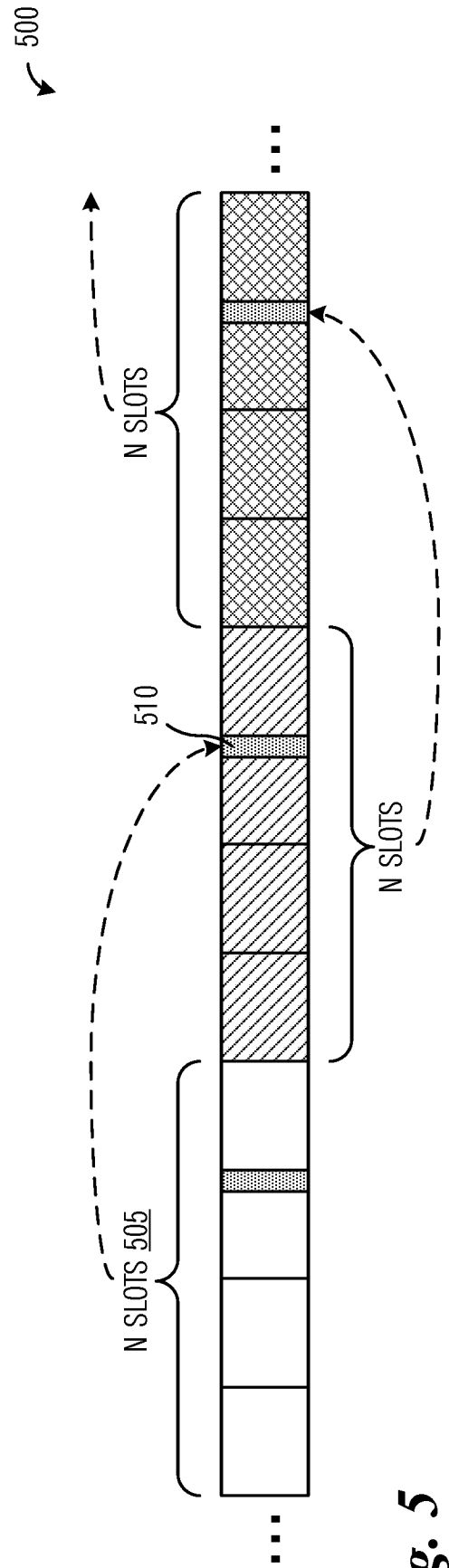
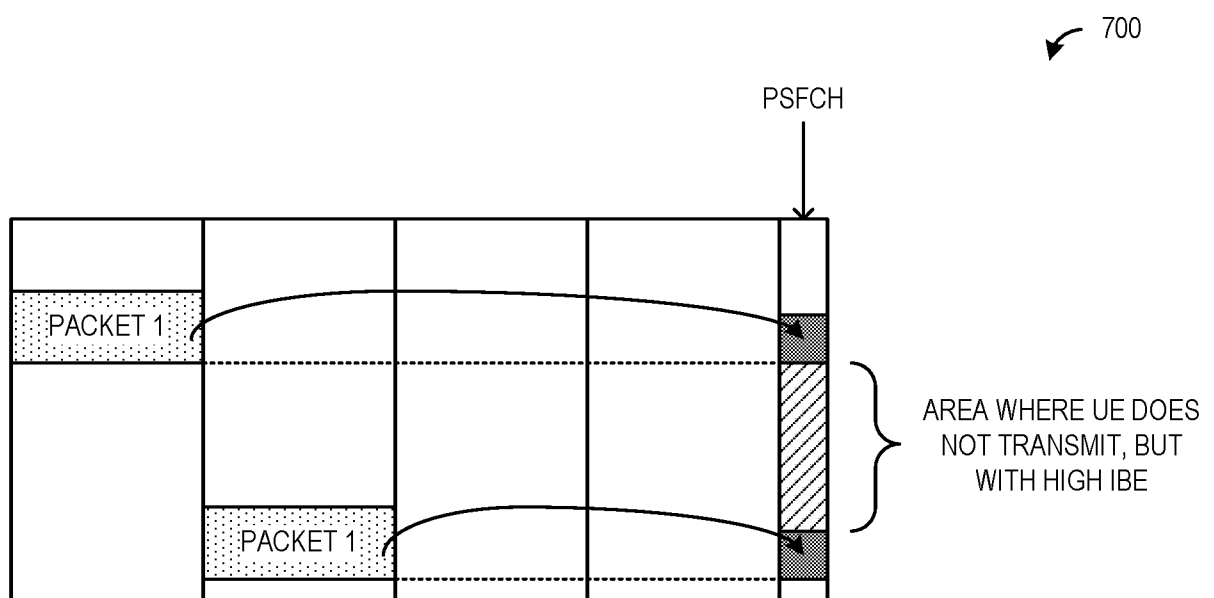
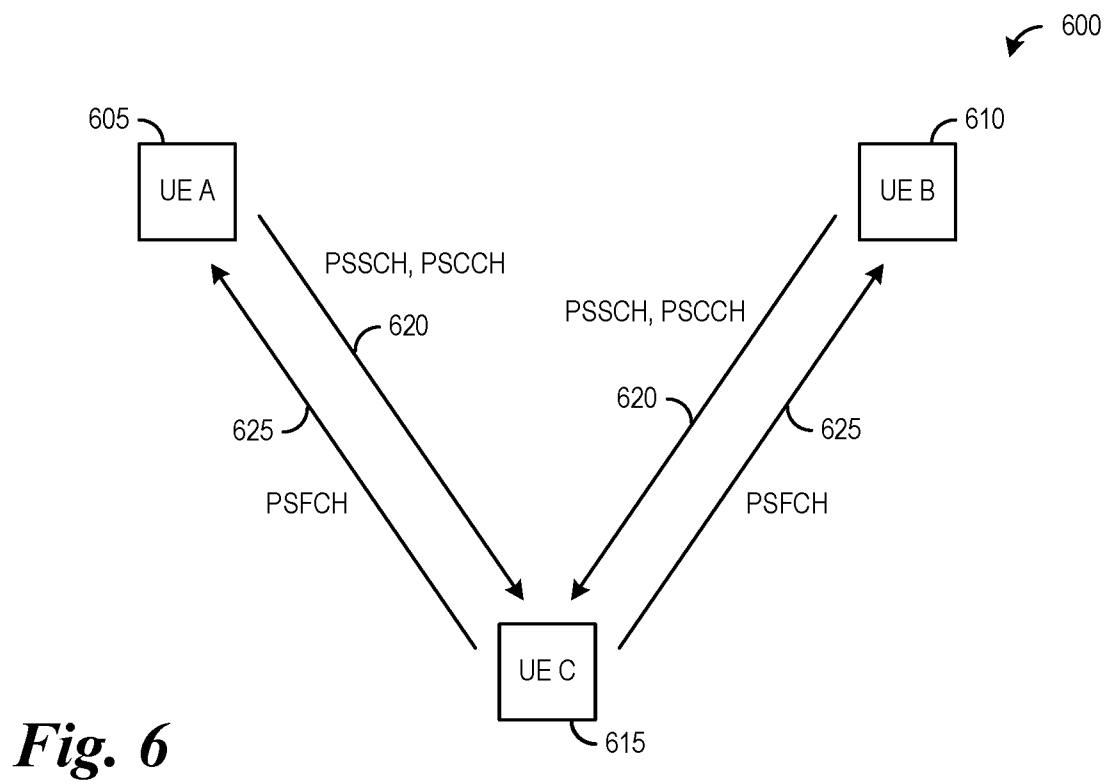
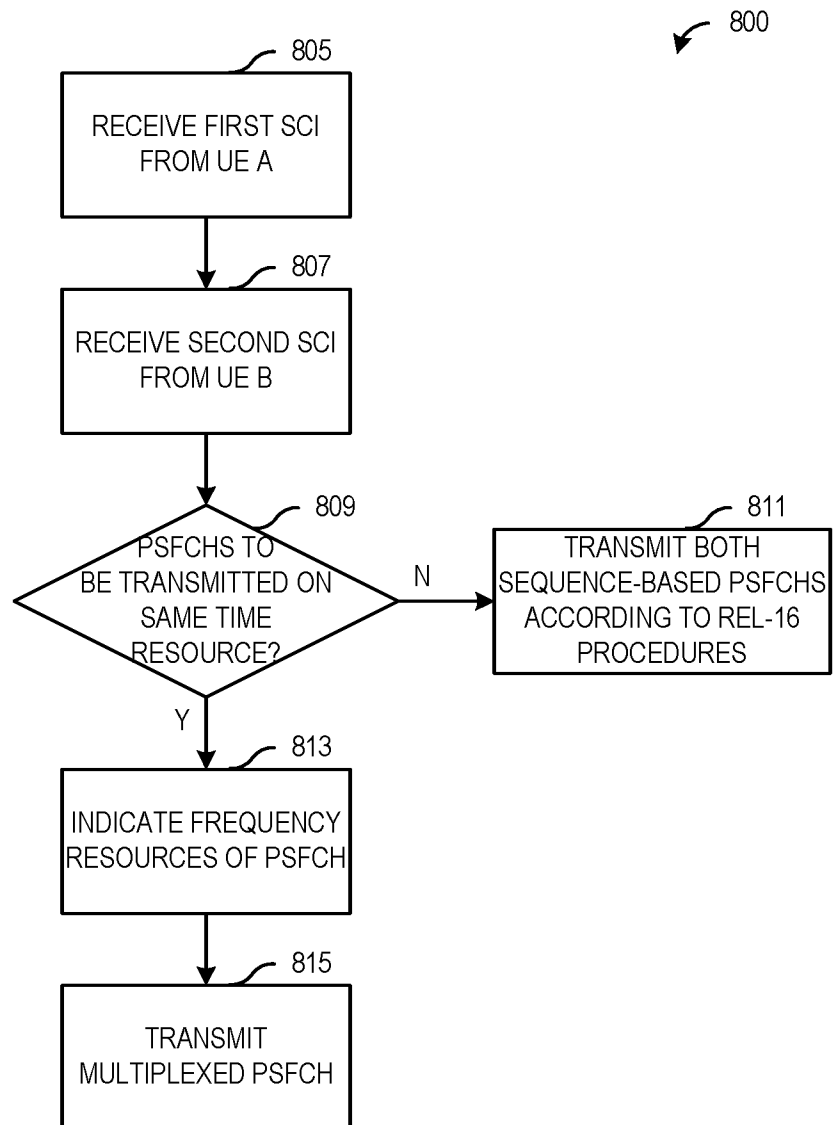


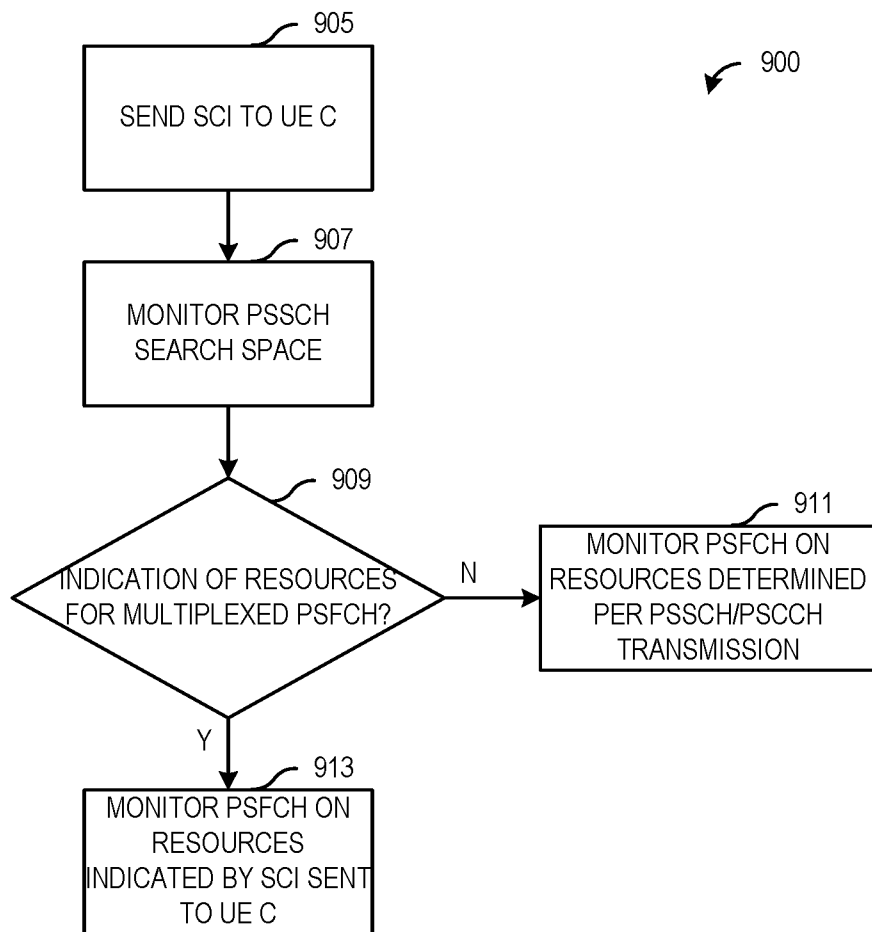
Fig. 5



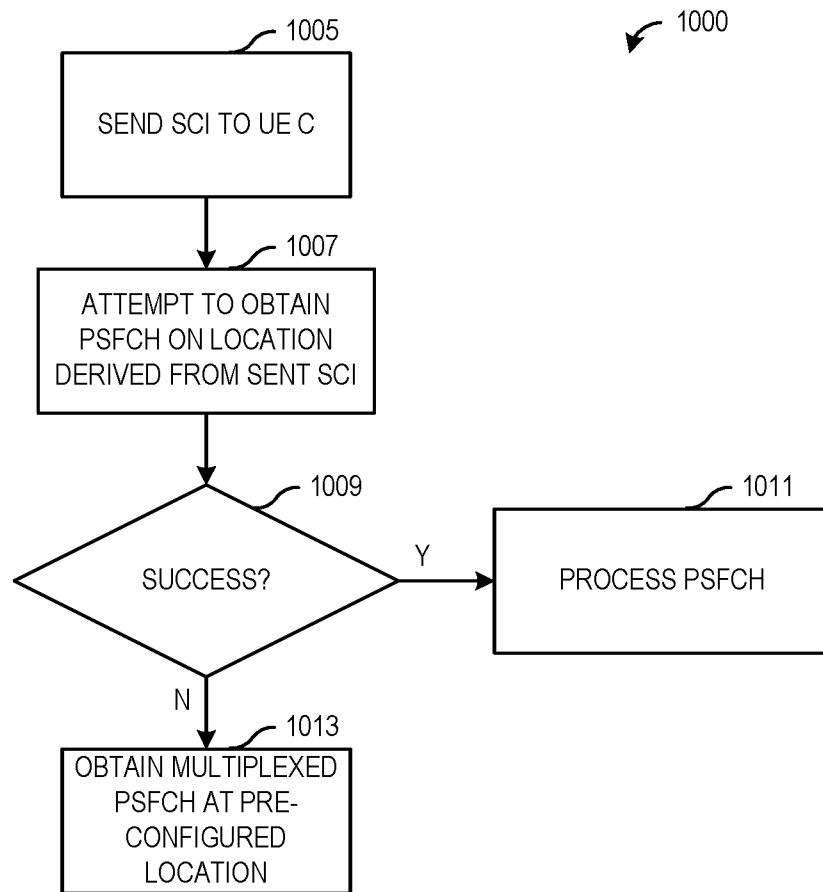
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**Fig. 8**

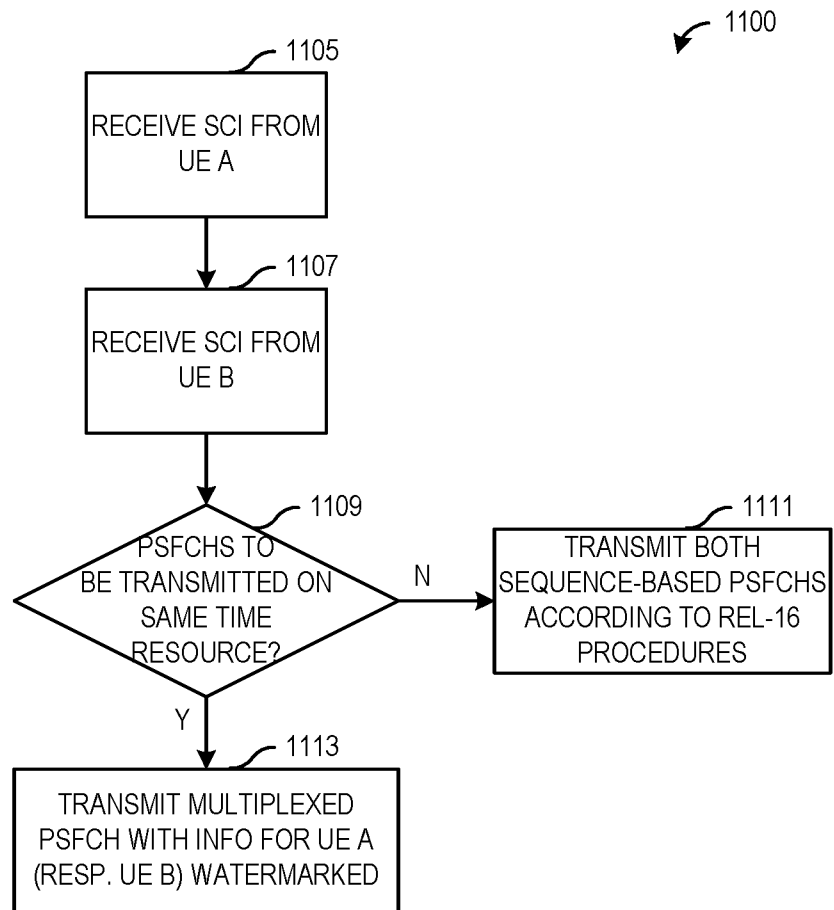
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**Fig. 9**

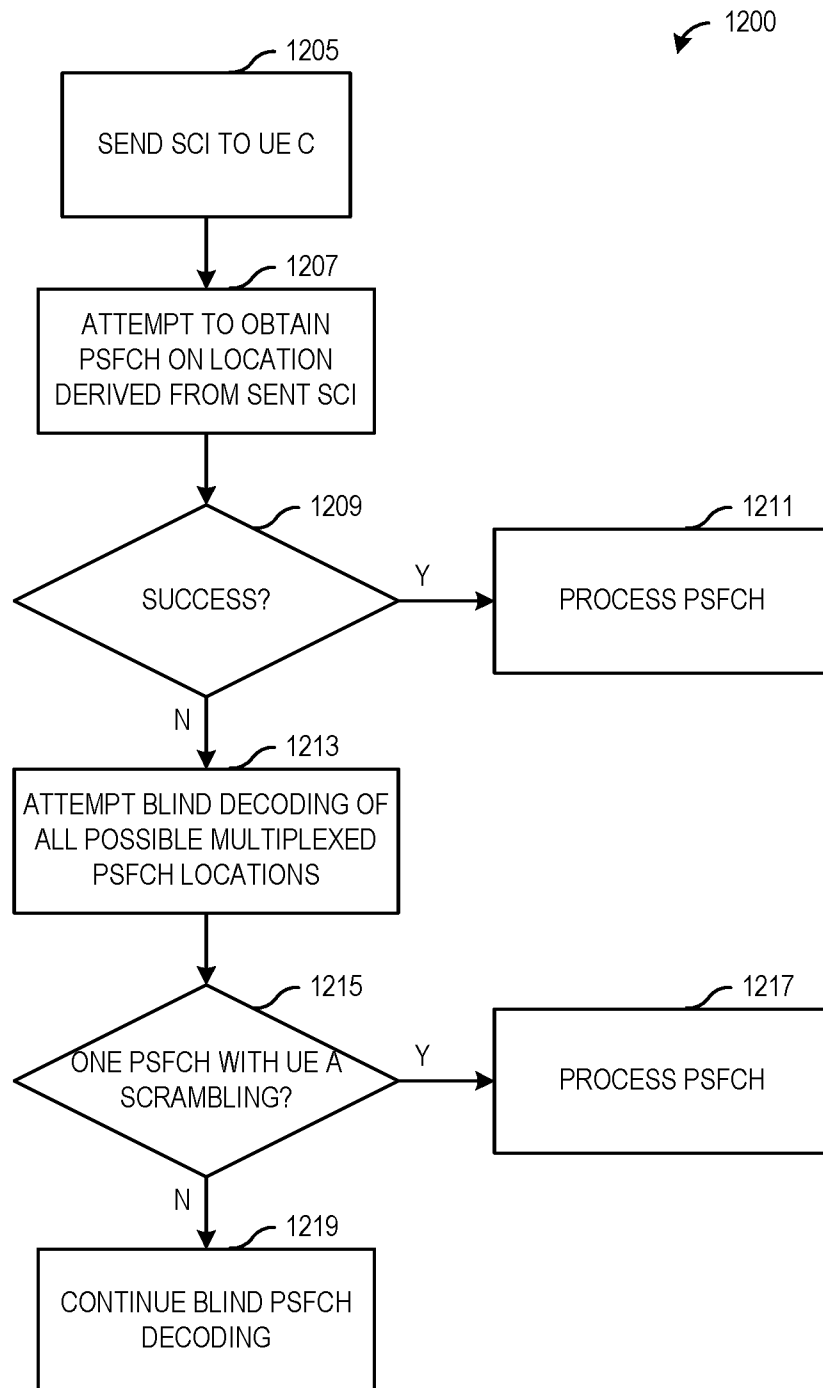
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**Fig. 10**

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**Fig. 11**

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**Fig. 12**

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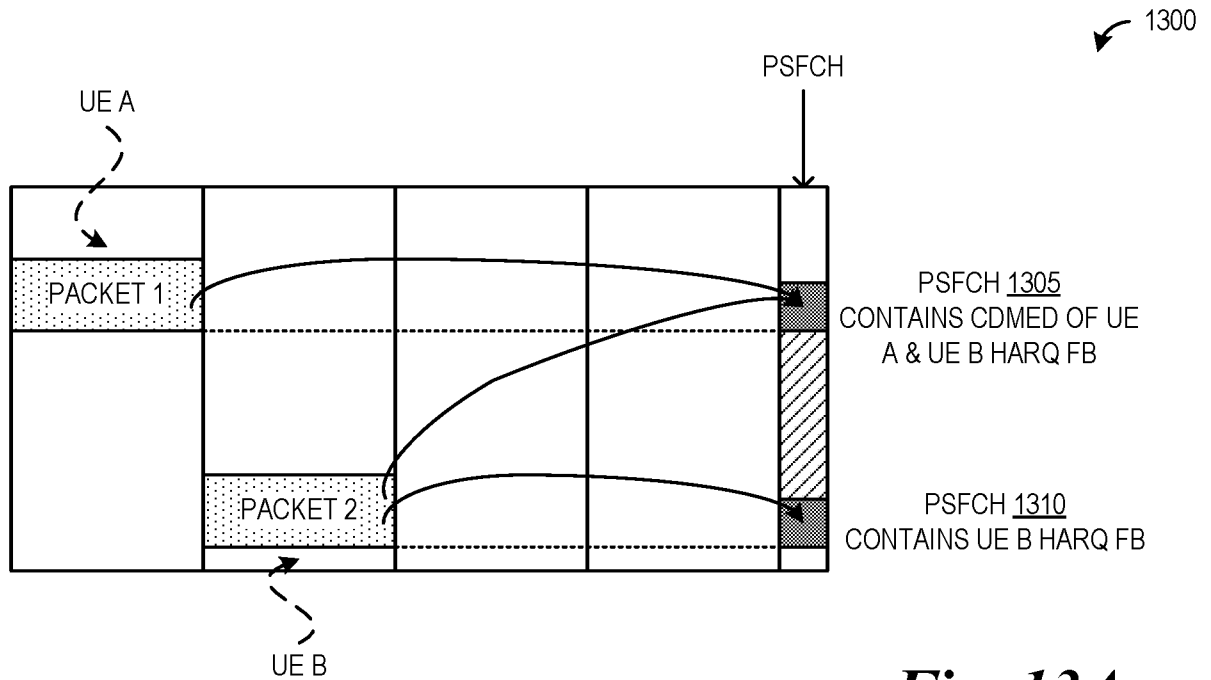


Fig. 13A

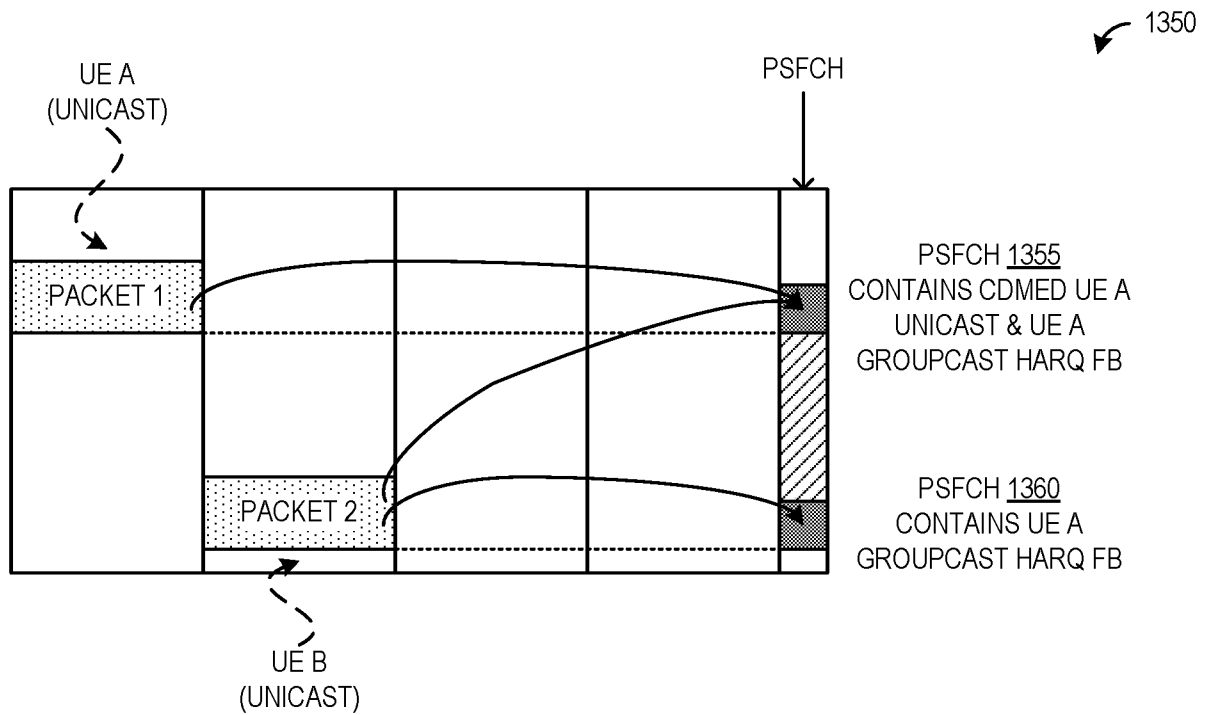
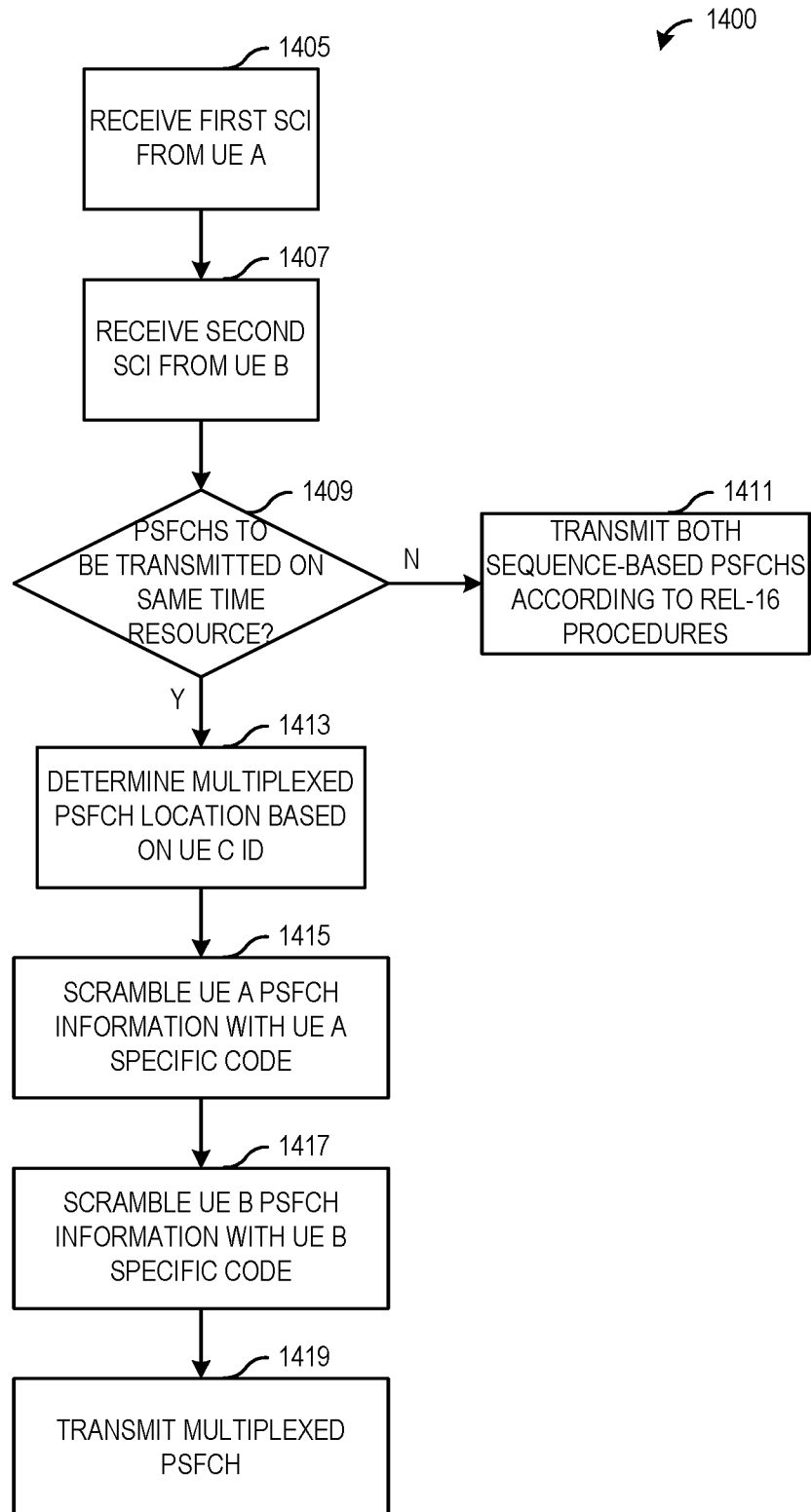
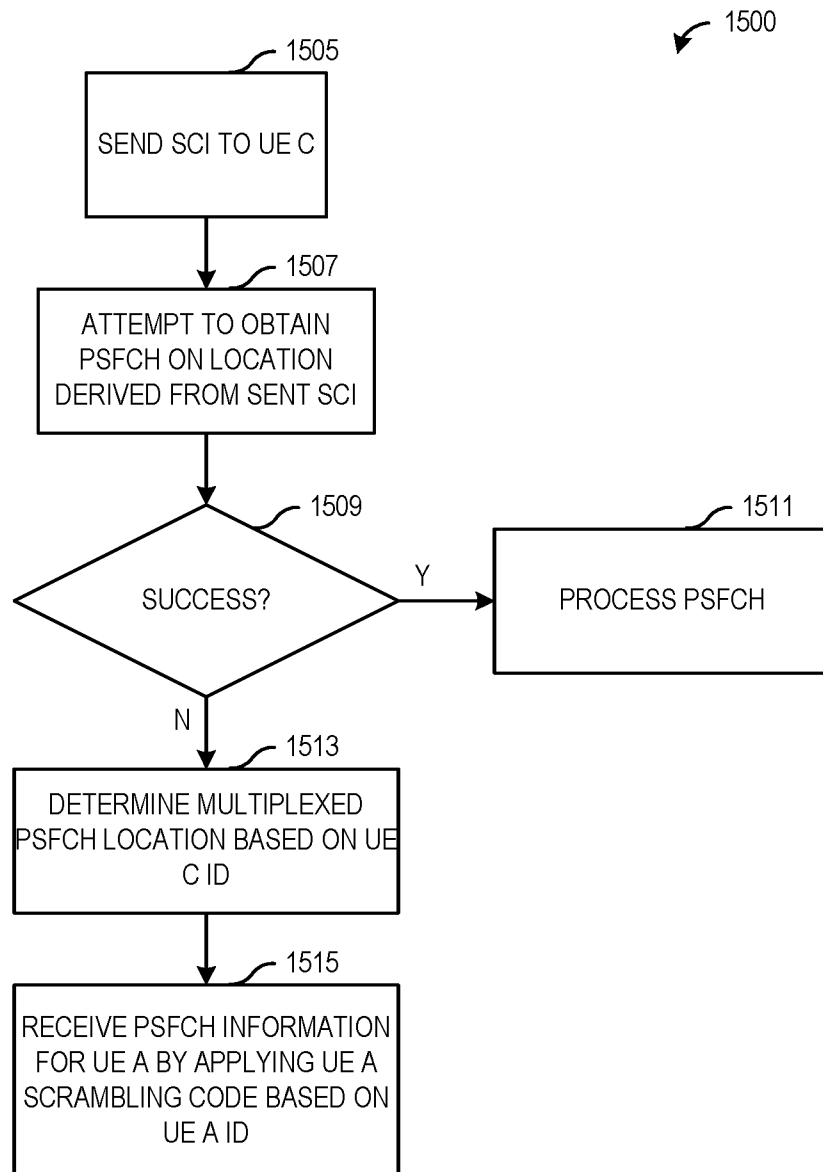


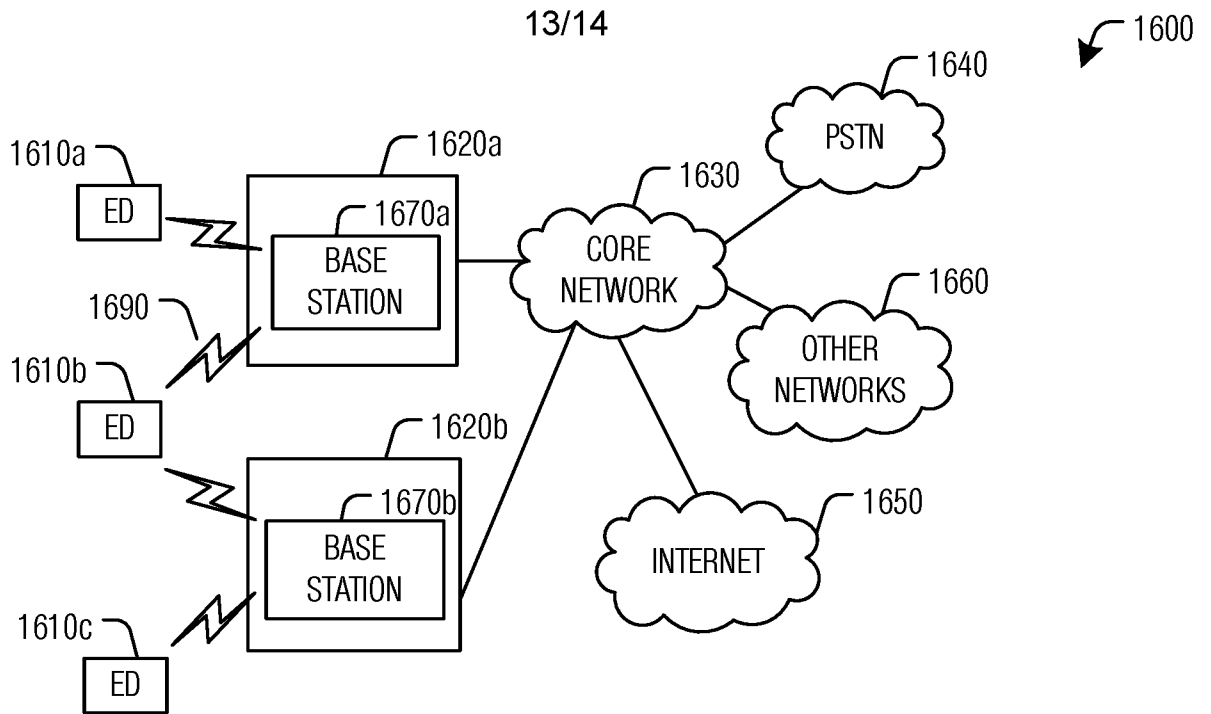
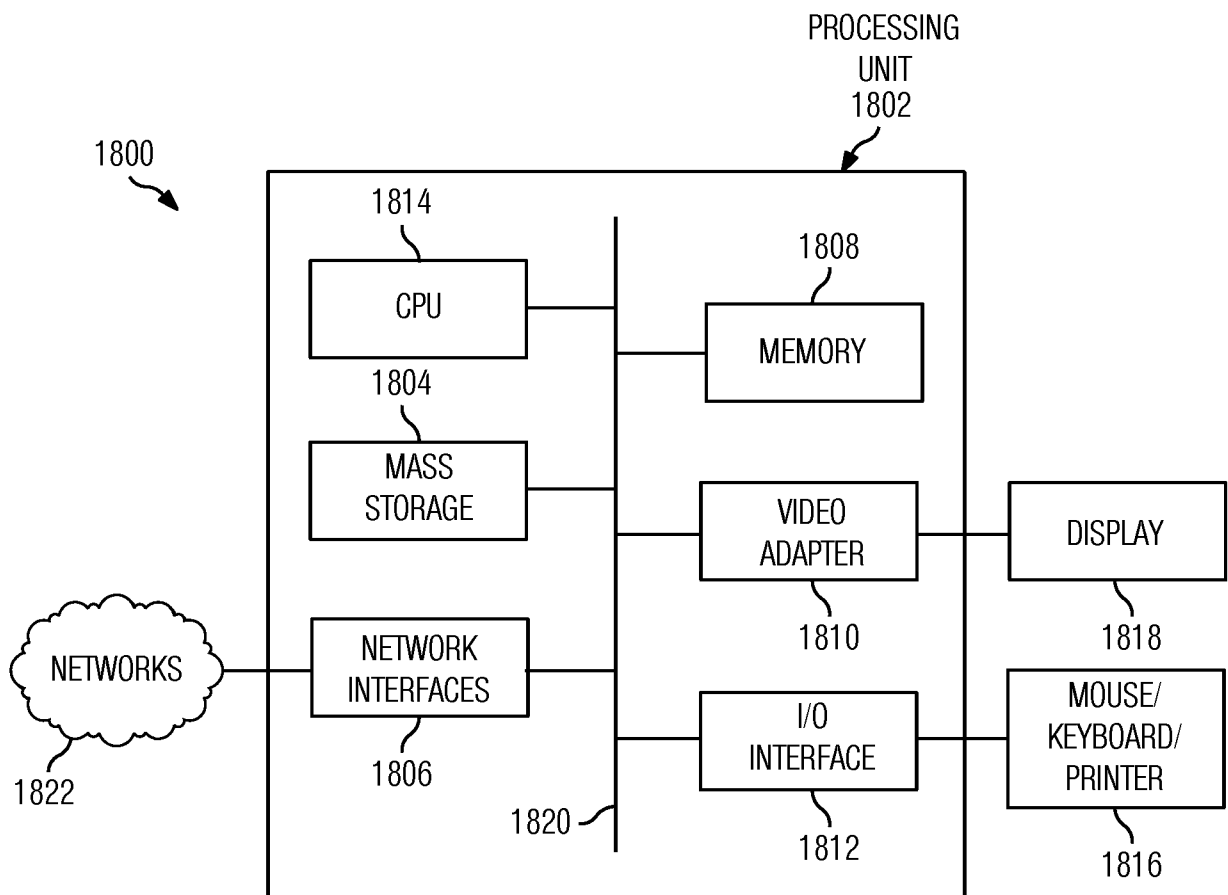
Fig. 13B

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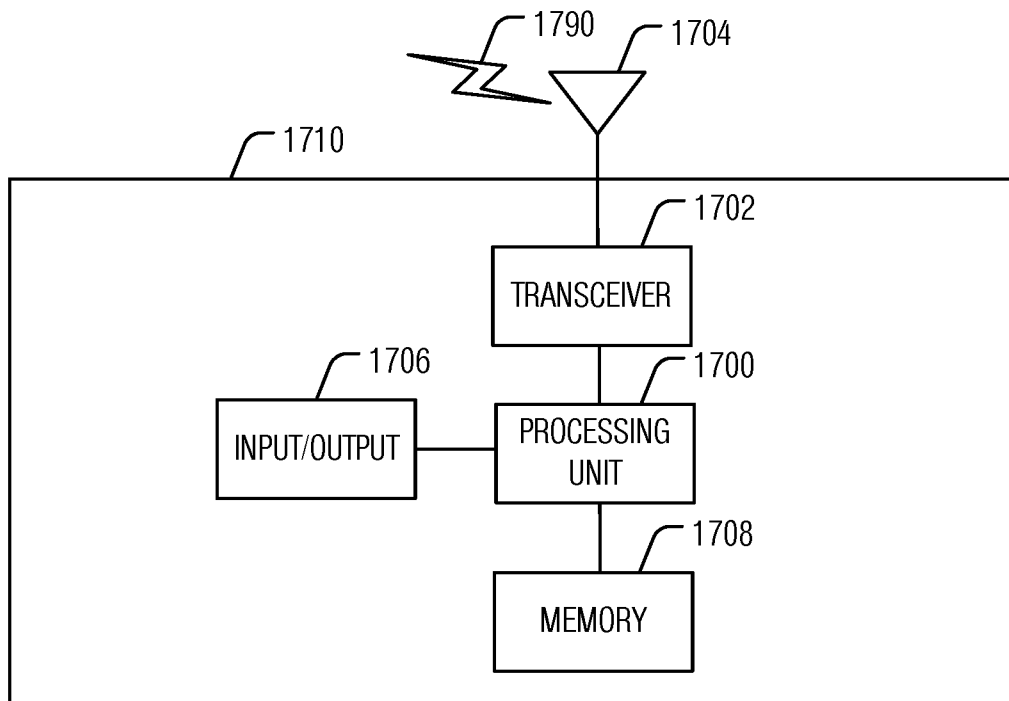
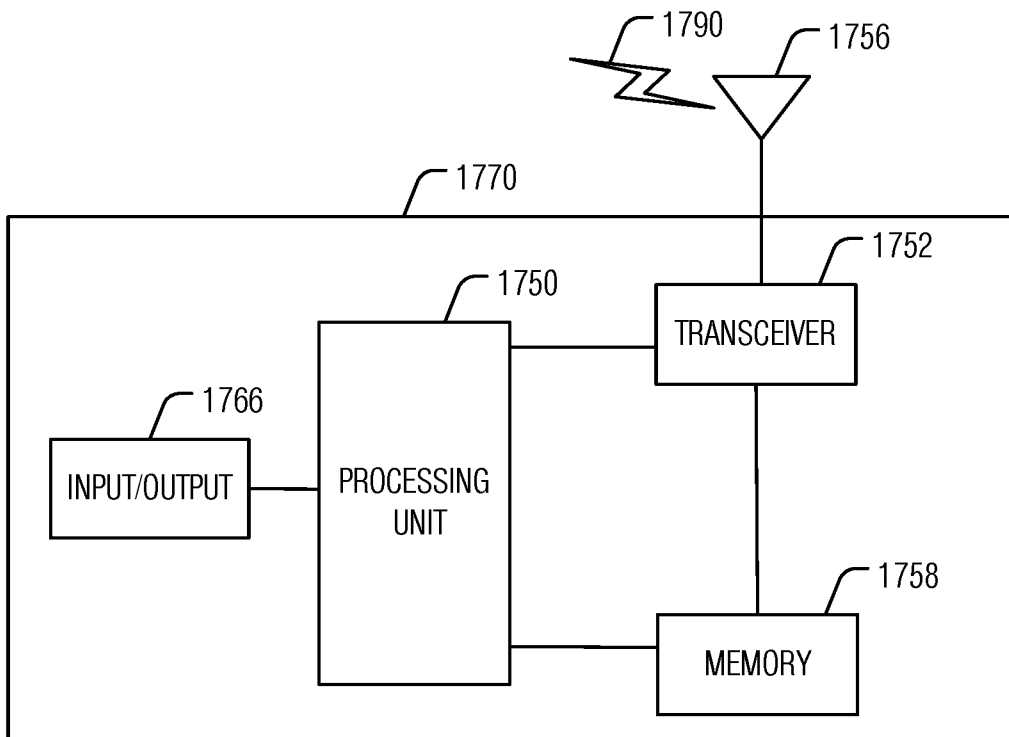
**Fig. 14**

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**Fig. 15**

**Fig. 16****Fig. 18**

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**Fig. 17A****Fig. 17B**