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- (54) **Title:** CONTROL SIGNALING MECHANISMS FOR ENHANCED DEVICE-TO-DEVICE (D2D)

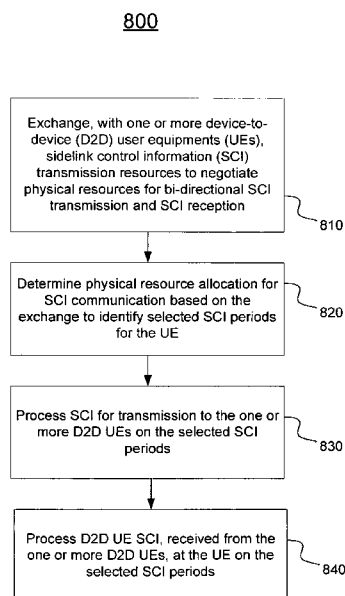


FIG. 8

- (57) **Abstract:** An apparatus of a User Equipment, UE, and a readable storage medium for control signaling for enhanced device-to-device, D2D, communication is disclosed. An UE exchanges (810), with one or more D2D UEs, sidelink control information, SCI, transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception. The UE determines (820) physical resource allocation for SCI communication based on the exchange to identify selected SCI periods for the UE. The UE processes (830) SCI for transmission to the one or more D2D UEs on the selected SCI periods. The UE processes (840) D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.



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CONTROL SIGNALING MECHANISMS FOR ENHANCED DEVICE-TO-DEVICE (D2D)

BACKGROUND

- 5 [0001] Wireless mobile communication technology uses various standards and protocols to transmit data between a node (e.g., a transmission station) and a wireless device (e.g., a mobile device). Some wireless devices communicate using orthogonal frequency-division multiple access (OFDMA) in a downlink (DL) transmission and single carrier frequency division multiple access (SC-FDMA) in an uplink (UL) and sidelink (SL) transmissions.
- 10 Standards and protocols that use orthogonal frequency-division multiplexing (OFDM) for signal transmission include the third generation partnership project (3GPP) long term evolution (LTE), the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard (e.g., 802.16e, 802.16m), which is commonly known to industry groups as WiMAX (Worldwide interoperability for Microwave Access), and the IEEE 802.11
- 15 standard, which is commonly known to industry groups as WiFi.
- [0002] In 3GPP radio access network (RAN) LTE systems, the node can be a combination of Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node Bs (also commonly denoted as evolved Node Bs, enhanced Node Bs, eNodeBs, or eNBs) and Radio Network Controllers (RNCs), which communicates with the wireless device,
- 20 known as a user equipment (UE). The downlink (DL) transmission can be a communication from the node (e.g., eNodeB) to the wireless device (e.g., UE), and the uplink (UL) transmission can be a communication from the wireless device to the node.
- [0003] Additionally, in 3rd generation partnership project (3GPP) long term evolution (LTE) Release 12, Device to device (D2D) discovery functionality is introduced to enable
- 25 D2D service. With direct D2D communication, a user equipment (UE) can communicate directly with each other without or with partial involvement of a base station or an evolved node B (eNB). One issue with D2D communication is device discovery to enable D2D service. Device discovery involves discovering one or more other discoverable UEs within communication range for D2D communication, such as in a one-to-many
- 30 (e.g., 1:many) D2D communication. Also, 3GPP LTE Release 12 defines several Sidelink physical and transport channels and corresponding procedures for D2D communication.
- [0004] However, current challenges relating to use of the Sidelink physical and transport

channels can prevent the efficient use of D2D communication for use cases, such UE-to-UE and UE-Network (NW).

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 [0005] Features and advantages of the disclosure will be apparent from the detailed description which follows, taken in conjunction with the accompanying drawings, which together illustrate, by way of example, features of the disclosure; and, wherein:
- [0006] FIG. 1 illustrates a mobile communication network within a cell in accordance with an example;
- 10 [0007] FIG. 2 depicts a legacy procedure for layer 1 (L1) device-to-device (D2D) communication in accordance with an example;
- [0008] FIG. 3 illustrates a transmission (Tx)-Reception (Rx) collision in a one-to-one communication in accordance with an example;
- [0009] FIG. 4 illustrates a logical period level orthogonalization in accordance with an example;
- 15 [0010] FIG. 5 illustrates an additional resource activation configuration in accordance with an example;
- [0011] FIG. 6 illustrates an example of time resource pattern for transmission (T-RPT) and sidelink control information (SCI) level orthogonalization in accordance with an example;
- 20 [0012] FIG. 7 depicts functionality of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs in accordance with an example;
- [0013] FIG. 8 depicts additional functionality of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs in accordance with an example;
- 25 [0014] FIG. 9 depicts additional functionality of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs in accordance with an example;
- [0015] FIG. 10 depicts additional functionality of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs in accordance with an example;
- 30

[0016] FIG. 11 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example;

[0017] FIG. 12 illustrates a diagram of example components of a User Equipment (UE) device in accordance with an example; and

5 [0018] FIG. 13 illustrates a diagram of a node (e.g., eNB) and wireless device (e.g., UE) in accordance with an example.

[0019] Reference will now be made to the exemplary embodiments illustrated, and specific language will be used herein to describe the same. It will nevertheless be understood that no limitation of the scope of the technology is thereby intended.

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DETAILED DESCRIPTION

[0020] Before the present technology is disclosed and described, it is to be understood that this technology is not limited to the particular structures, process steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those
15 ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular examples only and is not intended to be limiting. The same reference numerals in different drawings represent the same element. Numbers provided in flow charts and processes are provided for clarity in illustrating steps and operations and do not necessarily indicate a particular order or
20 sequence.

EXAMPLE EMBODIMENTS

[0021] An initial overview of technology embodiments is provided below and then specific technology embodiments are described in further detail later. This initial
25 summary is intended to aid readers in understanding the technology more quickly but is not intended to identify key features or essential features of the technology nor is it intended to limit the scope of the claimed subject matter.

[0022] In one aspect, 3GPP radio access network (RAN) LTE system can include an evolved universal terrestrial radio access network (E-UTRAN), which can include a
30 plurality of evolved Node-Bs (eNBs) and communicates with a plurality of mobile stations, also referred as user equipment (UEs). The radio protocol stacks of E-UTRAN are given including a radio resource control layer (RRC), a packet data convergence

protocol layer (PDCP), a radio link control layer (RLC), a media access control layer (MAC), and a physical layer (PHY).

[0023] In 3rd generation partnership project (3GPP) long term evolution (LTE) Release 12, Device to device (D2D) discovery functionality is defined to enable D2D service.

5 With direct D2D communication (e.g., “sidelink direct communication”), a user equipment (UE) can communicate directly with one or more D2D UEs without or with partial involvement of a base station or an evolved node B (eNB). Sidelink physical channels can carry synchronization related signals and information on a physical sidelink broadcast channel (PSBCH), device-to-device discovery using physical sidelink
10 discovery channel (PSDCH), device-to-device communication (e.g. voice service) data using a physical sidelink shared channel (PSSCH), and control signaling using a physical sidelink control channel (PSCCH). The functionality of sidelink physical channels can enable D2D discovery and D2D communication, such as in a one to many (e.g., 1:many) D2D communication. A defined physical layer functionality can be also reused without
15 modifications to enable other functions such as an internet protocol (IP)-layer routing for UE-to-network (NW) and UE-to-UE relay.

[0024] In one aspect, a technology is provided to enhance to sidelink physical channel procedures and functionality in order to support UE-to-Network relay functionality. One of the main components of the D2D relaying is efficient relay node discovery and unicast
20 (1:1) or multicast (1:many) communication. However, the physical layer functionality of 3GPP LTE Release 12 limits the D2D communication. For example, the physical layer functionality of 3GPP Release 12 does not support at least one or more of: 1) link adaptation, 2) acknowledgment (ACK/NACK) feedbacks, 3) efficient bi-directional resource allocation and management, 4) cluster/group management, and/or 5) UE-UE and
25 UE-to-Network relay. These limitations can impose certain constraints on voice over internet protocol (VoIP) and video traffic in UE-to-NW and/or UE-to-UE relaying while also having significant power consumption.

[0025] Thus, in one aspect, the present technology provides signaling procedures to enable the physical layer functionality, such as layer 1 (L1) and layer 2 (L2), L1/L2
30 functionality, on top of a sidelink physical layer, such as a 3GPP LTE Release 12 Sidelink physical layer. In one aspect, signaling can extend the existing 3GPP LTE Release 12 sidelink physical layer to enable more efficient operation for new use cases, such as, for

example, a UE-to-NW relay and/or a UE-UE relay.

[0026] In one aspect, the present technology reuses a sidelink physical layer. However, the 3GPP LTE Release 12 D2D PHY is not optimized for unicast (1:1) or one-to-many (1:many) communication and D2D relaying. In one aspect, the present technology enables more efficient D2D communication while minimizing the impact on the existing L1 layer. In one aspect, a technology is provided for D2D functionality by means of a sidelink physical channel and transport channels and corresponding procedures.

[0027] In one aspect, a technology is provided for control signaling for enhanced device-to-device (D2D) communication. A user equipment (UE) can exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception. The UE can determine physical resource allocation for SCI communication based on the exchange. The UE can process SCI for transmission to the one or more D2D UEs on a selected SCI period. The UE can process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.

[0028] In one aspect, a technology is provided for control signaling for enhanced device-to-device (D2D) communication. A user equipment (UE) can process a blind sidelink control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information. The UE can process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH) according to the SCI transmission. The UE can process, for transmission, to the second UE the D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI).

[0029] FIG. 1 illustrates a mobile communication network within a cell 100 having an evolved node B (eNB) with a mobile device. FIG. 1 illustrates an eNB 104 that can be associated with an anchor cell, macro cell or primary cell. Also, the cell 100 can include mobile device, such as, for example, a User equipment (UE or UEs) 108 that can be in communication with the eNB 104. The eNB 104 can be a station that communicates with the UE 108 and can also be referred to as a base station, a node B, an access point, and the like. The eNB 104 can be a high transmission power eNB, such as a macro eNB, for coverage and connectivity. The eNB 104 can be responsible for mobility and can also be

responsible for radio resource control (RRC) signaling. User equipment (UE or UEs) 108 can be supported by the macro eNB 104. The eNB 104 can provide communication coverage for a particular geographic area. In 3GPP, the term “cell” can refer to a particular geographic coverage area of eNB and/or an eNB subsystem serving the coverage area, depending on the context in which the term is used.

[0030] It should be noted that a UE communication can be described using the Open Systems Interconnect (OSI) model, comprising multiple layers: Layer 1, Layer 2, and Layer 3. Layer 1 (L1 layer) can be the lowest layer and implements various physical layer signal processing functions. The L1 layer will be referred to herein as the physical layer.

Layer 2 (L2 layer) can be above the physical layer and can be responsible for the link between the UE and one or more D2D UEs over the physical layer. In a user plane, the L2 layer can include a media access control (MAC) sublayer, a radio link control (RLC) sublayer 512, and a packet data convergence protocol (PDCP). The UE can have several upper layers above the L2 layer including a network layer (e.g., IP layer) and an application layer.

[0031] FIG. 2 depicts a legacy procedure for layer 1 (L1) device-to-device (D2D) communication 200. FIG. 2 illustrates a transmitting UE (Tx UE), a receiving UE (Rx UE), a sidelink channel information pool (e.g., a physical sidelink control channel “PSCCH”) and a data pool (e.g., a physical sidelink shared channel “PSSCH”, sidelink control information (SCI), and time resource pattern for transmission (T-RPT). In D2D communication, source and destination identities can be used to filter out a corresponding data at layers 1, 2, and 3. The L1 can contain a shortened source identity. Thus, a UE can be configured to process redundant physical layer messages in order to receive data of interest. Moreover, even in case of low data rate traffic, a receiving UE (RX UE) may process an entire allocated data resource pool, if the UE successfully decodes a sidelink control information (SCI) message from a transmitter (Tx UE) of interest, as illustrated in FIG. 2. As depicted in FIG. 2, a substantial part of the allocated time resource pattern for transmission (T-RPT) is not utilized for transmission, and a receiving UE (Rx UE) can waste processing resources and energy trying to process resources without data.

[0032] FIG. 3 illustrates a transmission (Tx)-Reception (Rx) collision in a one-to-one communication 300. In case of bi-directional traffic, as in FIG. 3, the problems are even more complicated, because transmission and reception collisions, such as for an SCI pool

and a data pool on a physical shared control channel (PSCCH), can appear at the same UE. For example, collisions that are due to a half-duplex constraint can appear at the same UE, which prohibit the device from simultaneous transmission and reception resulting in lost transmissions for SCI and/or Data packets.

5 [0033] In a case of sidelink transmission Mode-1 (eNB scheduled), when the eNB schedules D2D transmissions, it is possible to allocate the SCI and the PSSCH resources for both sides of the sidelink in a way to minimize half-duplex collisions and orthogonalize data traffic from different directions in time. Thus, special information from a Buffer Status Report (BSR) can be used. In the case of sidelink transmission
10 Mode-2 (autonomous UE), UEs can select frequency and time resources for transmission autonomously, and orthogonal transmissions can be probabilistically possible. It should be noted that the special information can include information where a first UE reports in the BSR a destination identity of an alternative UE with which the first UE wants to communicate. This alternative UE also does the same process for the first UE (e.g.,
15 reports a BSR to the eNB with identity of the first UE. Finally, the eNB is able to know who wants to communicate with whom and thus may have an idea how to orthogonalize transmissions of these 2 UEs. The probabilistic selection of orthogonal in-time resources can be due to a specified procedure of a T-RPT selection. In Mode-2, a T-RPT can be selected uniformly randomly from the entire set of resource patterns, which can
20 optionally be restricted to a reduced subset. Each pattern can be restricted to a small subset of mutually orthogonal patterns. For example, in the case of frequency division duplexing (FDD), there are 106 different patterns without restriction.

[0034] Resource patterns with $k=1$ (one transmission per 8 sidelink subframes) have 7 mutually orthogonal T-RPT bitmaps. This translates to substantial collision probability
25 when T-RPT is selected randomly, as illustrated in FIG. 3.

[0035] Thus, in order to prevent these challenges and collisions, the present technology provides for control signaling to negotiate used physical resources. Special control information can be exchanged between devices to negotiate physical resources for transmission and reception in case of bidirectional one-to-one communication. The
30 information exchange can be initiated by any of two devices participating in communication or be a part of initial transmission of each device. In one aspect, different rules can be defined to select orthogonal resources in different procedures (e.g. one-to-

one relay connection establishment).

Negotiation or configuration of transmission periodicity for different functions

[0036] In one aspect, the transmission resources among two UEs or a group of UEs
5 involved into D2D communication can be orthogonalized by utilizing different sidelink
control information (SCI) (also known as SA – scheduling assignment) periods/pools.
Periodically allocated physical resources can be used for construction of control and data
pools and D2D capable UEs can be used to monitor the SCI pools and data pools. Future
3GPP LTE releases can be employed by configuring a “logical” transmission periods with
10 different functionalities on top of the frequently configured physical resources.

[0037] Turning now to FIG. 4, logical period level orthogonalization 400 is depicted. In
one aspect, existing L1 functionality of random SCI resource and T- RPT selection can be
reused. For example, in order to reuse existing L1 functionality of random SCI resource
and T- RPT selection, logical scheduling cycles can be introduced. In one example, a
15 logical transmission pattern can be configured such as a first UE (e.g., UE 1) transmits
every even SCI period and the second UE (e.g., UE 2) can transmit every odd SCI period,
as illustrated in a logical period level orthogonalization of FIG. 4.

[0038] Alternatively, a logical transmission pattern can occupy a part of an SCI period
(logical PSSCH pool), such as a first UE, such as UE1, transmits at the first half of the
20 PSSCH pool, and the second UE, such as UE 2, transmits in the remaining half of the
PSSCH period, skipping the initial transmission opportunities. The latter example can
lead to collisions on bounds of the halves of PSSCH pool since the particular pool bitmap
pattern and selected T-RPT cannot allow dividing resources on equal parts. In this case,
the transmission on collided resource can be postponed and/or dropped. Another problem
25 for the latter embodiment is the probability of SCI resource collision since the SCI
resources are selected randomly in Mode-2.

[0039] Accordingly, a desired logical transmission period pattern between two or more of
UEs can be negotiated or configured through dedicated higher layer signaling. In out of
network coverage scenarios, some SCI periods can be preconfigured. For instance, a UE-
30 to-NW discovery announcement rate can be configured to be a multiple of the sidelink
data and control physical periods (e.g., an SCI period).

[0040] In one aspect, the D2D physical communication channel can be used for UE-to-

network (NW) relay discovery, because of significantly larger payload sizes (e.g., larger being greater than 232 bits) of relay discovery messages comparing to D2D discovery channel. This option can be more applicable if low latency and large payload messages are exchanged. A communication channel can be also used if there are no physical
5 discovery resources configured.

[0041] In one aspect, in a UE-to-NW scenario, a single UE can have multiple D2D communication connections to handle multiple discovery responses. It should be noted that it to have a large number of orthogonal in time one-to-many (1:1) connections on a single UE due to random nature of Mode-2, if legacy 3GPP Release 12 UE procedures for
10 resource selection are reused. To allow this use case, a UE, that establishes one or more multiple one-to-many (1:1) connections can additionally provide control information for receiving UEs and inform the receiving UEs about a transmit resource selection in order to avoid half-duplex constraint.

[0042] In one aspect, for low data rate services (as discovery through D2D
15 communication), a logical transmission zone can be configured and applied on top of an existing SCI resource pool and data resource pool configurations and signaled as a resource activation bitmap over SCI periods. For example, the resource activation bitmap of one '1' can indicate which SCI period is activated for such transmissions and '0' can indicate a prohibited SCI period, as depicted in FIG. 5, illustrating an additional resource
20 activation configuration 500. The configuration signaling can also be placed in a physical sidelink broadcast channel (PSBCH) or be a part of network RRC SIB signaling or negotiated through PSCCH/PSSCH channel on a D2D link.

[0043] Such resource configuration can facilitate more efficient participation of UEs in discovery through communication since the UEs can wake up, synchronize, and activate
25 D2D communication functions only in a pre-configured time windows while staying in a sleep mode all the remaining periods.

T-RPT and SCI resource level negotiation:

[0044] D2D transmissions can be orthogonalized in time by selecting orthogonal or
30 quasi-orthogonal in time resources for SCI and data transmission. In one aspect, once a UE decoded SCI and corresponding data of interested TX UE, the UE can select SCI and data transmission resources from a subset that is orthogonal to SCI resource and T-RPT

used by a first TX UE, as depicted in FIG. 6. FIG. 6 illustrates an example of time resource pattern for transmission (T-RPT) and sidelink control information (SCI) level orthogonalization 600. However, one challenge is that currently for each SCI period the resources for SCI and data transmission can be selected randomly without any condition on the previously selected resources. To enable the proposed T-RPT and SCI level orthogonalization, the resources for Mode-2 transmission can be configured by higher layers. In other words, the random resource selection can be optional if higher layers provide the resource configuration.

10 **Signaling options:**

[0045] It should be note that functionality described herein can be enabled by introduction of additional control signaling over D2D links. The following options can be foreseen: 1) physical layer signaling. New SCI format (e.g. SCI Format 1) can be introduced to set up resources for 1:1 communication. A new SCI Format can have the same size as SCI Format 0. The SCI formats can be distinguished by either setting T-RPT index to a reserved value, or scrambling the SCI payload or CRC with some predefined sequence. Additionally, a dedicated resource pool can be allocated for new SCI format.

15 [0046] Higher layer signaling can be provided. For example, the L2 or higher layer control signaling carried in physical sidelink shared channel (PSSCH) can be used to control D2D operation over physical resource. This option is much more flexible in terms of the amount of control signaling that can be transmitted and in terms of functionality that can be enabled. Additionally, it can have good link budget and robustness against interference due to 4 blind retransmissions, used at the PSSCH. The control information can be also encoded at PDCP layer or higher. For instance, the PC5 Signaling Protocol or PC5-D protocol can be used to exchange the control messages and control/configure D2D operation at lower layers, e.g. physical layer.

Additional content of control signaling for efficient 1:1 communication

30 [0047] Since the resources for one-to-one 1:1 communication can be negotiated using the solutions provided herein (e.g. layer 2 control signaling), additional control information can be efficiently exchanged on a 1:1 link during communication.

[0048] In one aspect, during the selected SCI periods to the one or more D2D UEs

control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

- [0049] For the ACK/NACK, the layer 2 acknowledgement can be efficiently enabled
5 through dedicated feedback message. As for link adaptation information, sidelink functionality lacks channel quality feedback. However, if having stable reverse channel through resource negotiation mechanism, it is possible to send a feedback on a per SCI period or per transmission opportunity (or other granularity level). The feedback can contain channel quality indicator, precoding index, rank, target MCS, desirable T-RPT,
10 frequency allocation, desirable SCI resource index, etc. In one aspect, the resource negotiation indication can also be assumed as a feedback type. In one aspect, resource control and allocation signaling can be sent in case one of the UEs takes a role of resource coordinator or the head of a cluster or group. The signaling can provide a floor control, resource allocation for a UE, scheduling information including MCS, and power settings.
- [0050] FIG. 7 depicts a flow chart of a user equipment (UE) operable to perform for
15 control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs. A UE, such as UE1, can receive, from one or more D2D UEs, such as UE2, D2D control information with a resource negotiation and activation message. The UE, such as UE1, can transmit to the one or more D2D UEs, such as UE2, D2D control
20 information with a response to the resource negotiation and activation message. The UE, such as UE1, can receive from the one or more D2D UEs, such as UE2, a sidelink control information (SCI) transmission in physical sidelink control channel (PSCCH) that can include D2D control information. The UE, such as UE1, can receive, from the one or more UEs, such as UE2, a SCI (e.g., blink decoding over the PSCCH) and can acquire
25 information about a subsequent data transmission. The information with a response to the resource negotiation and activation message. The UE, such as UE1, can receive from the one or more D2D UEs, such as UE2, broadcast D2D data in a physical sidelink shared channel (PSSCH) according to the SCI. The UE, such as UE1, can receive from the one or more D2D UEs, such as UE2, D2D data. The UE, such as UE1, can send to the one or
30 more D2D UEs, such as UE2, D2D control information with feedback that can include acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and/or a channel quality indicator (CQI).

[0051] FIG. 8 depicts functionality 800 of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs. The functionality 800 can be implemented as a method or the functionality 800 can be executed as instructions on a machine, where the instructions are included on one or more computer readable medium or one or more non-transitory machine readable storage medium. One or more processors and memory can be configured to exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception, as in block 810. One or more processors and memory can be configured to determine physical resource allocation for SCI communication based on the exchange to identify selected SCI periods for the UE, as in block 820. One or more processors and memory can be configured to process SCI for transmission to the one or more D2D UEs on the selected SCI periods, as in block 830. One or more processors and memory can be configured to process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods, as in block 840.

[0052] FIG. 9 depicts functionality 900 of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or more D2D UEs. The functionality 900 can be implemented as a method or the functionality 900 can be executed as instructions on a machine, where the instructions are included on one or more computer readable medium or one or more non-transitory machine readable storage medium. One or more processors and memory can be configured to exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception, as in block 910. One or more processors and memory can be configured to determine physical resource allocation for SCI communication based on the exchange, as in block 920. One or more processors and memory can be configured to process SCI for transmission to the one or more D2D UEs on a selected SCI period, as in block 930. One or more processors and memory can be configured to process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods, as in block 940.

[0053] FIG. 10 depicts functionality 1000 of a user equipment (UE) operable to perform for control signaling for enhanced device-to-device (D2D) communication with one or

more D2D UEs. The functionality 1000 can be implemented as a method or the functionality 1000 can be executed as instructions on a machine, where the instructions are included on one or more computer readable medium or one or more non-transitory machine readable storage medium. One or more processors and memory can be
5 configured to process a blind sidelink control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information, as in block 1010. The one or more processors and memory can be configured to process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH) according to the SCI transmission, as in block 1020. The one or more
10 processors and memory can be configured to process, for transmission, to the second UE the D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI), as in block 1030.

[0054] In one aspect, one or more actions of FIGs 7-10, can include configuring, by the
15 UE, resources to be used for D2D transmission of data and control; configuring, by the UE, resources to be used for D2D reception of data control; sending, by the UE, control messages with a feedback payload; sending, by the UE, resources configuration and other control information inside a feedback; receiving, by the UE, resources configuration and other control information inside a feedback; and receiving, by the UE, control messages
20 inside the configured resources. A dedicated SCI format can be used to transmit control information. A higher layer control signaling protocol can be used to transmit control information. The higher layer control signaling can be encoded and transmitted in PSSCH or PSDCH.

[0055] In one aspect, the control messages can include one or more resource (re)-
25 configuration, ACK/NACK signaling, a Channel State Information (CSI), a channel quality indicator (CQI), a precoding index, a rank, target MCS, an index of a time resource pattern for transmission (T-RPT), a frequency allocation, and/or a SCI resource index. The control messages can include resource scheduling information for a group and/or a cluster of UEs. The resource configuration can comprise logical cycles where
30 transmission is allowed. The resource configuration can include of a bitmap over SCI periods where a '1' activates corresponding SCI period for transmission and '0' deactivates. The logical cycles can be a multiple or a fraction of a SCI period. The

resource configuration can include a SCI resource index and T-RPT for intended UEs.

[0056] FIG. 11 illustrates a diagram of a wireless device (e.g., UE) in accordance with an example. FIG. 11 provides an example illustration of the wireless device, such as a user equipment (UE), a mobile station (MS), a mobile wireless device, a mobile

5 communication device, a tablet, a handset, or other type of wireless device. In one aspect, the wireless device can include at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, a baseband processor, an application processor, internal memory, a non-volatile memory port, and combinations thereof.

10 [0057] The wireless device can include one or more antennas configured to communicate with a node or transmission station, such as a base station (BS), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a relay station (RS), a radio equipment (RE), a remote radio unit (RRU), a central processing module (CPM), or other type of wireless wide area network (WWAN) access
15 point. The wireless device can be configured to communicate using at least one wireless communication standard including 3GPP LTE, WiMAX, High Speed Packet Access (HSPA), Bluetooth, and WiFi. The wireless device can communicate using separate antennas for each wireless communication standard or shared antennas for multiple wireless communication standards. The wireless device can communicate in a wireless
20 local area network (WLAN), a wireless personal area network (WPAN), and/or a WWAN. The mobile device can include a storage medium. In one aspect, the storage medium can be associated with and/or communication with the application processor, the graphics processor, the display, the non-volatile memory port, and/or internal memory. In one aspect, the application processor and graphics processor are storage mediums.

25 [0058] FIG. 12 illustrates, for one aspect, example components of a User Equipment (UE) device 1200. In some aspects, the UE device 1200 can include application circuitry 1202, baseband circuitry 1204, Radio Frequency (RF) circuitry 1206, front-end module (FEM) circuitry 1208 and one or more antennas 1210, coupled together at least as shown.

[0059] The application circuitry 1202 can include one or more application processors.
30 For example, the application circuitry 1202 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) can include any combination of general-purpose processors and dedicated processors (e.g., graphics

processors, application processors, etc.). The processors can be coupled with and/or can include a storage medium 1212, and can be configured to execute instructions stored in the storage medium 1212 to enable various applications and/or operating systems to run on the system.

5 [0060] The baseband circuitry 1204 can include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1204 can include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 1206 and to generate baseband signals for a transmit signal path of the RF circuitry 1206. Baseband processing circuitry
10 1204 can interface with the application circuitry 1202 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1206. For example, in some aspects, the baseband circuitry 1204 can include a second generation (2G) baseband processor 1204a, third generation (3G) baseband processor 1204b, fourth generation (4G) baseband processor 1204c, and/or other baseband processor(s) 1204d for
15 other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 1204 (e.g., one or more of baseband processors 1204a-d) can handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1206. The radio control functions can include, but are not limited to, signal
20 modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some aspects, modulation/demodulation circuitry of the baseband circuitry 1204 can include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some aspects, encoding/decoding circuitry of the baseband circuitry 1204 can include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density
25 Parity Check (LDPC) encoder/decoder functionality. Aspects of modulation/demodulation and encoder/decoder functionality are not limited to these examples and can include other suitable functionality in other aspects.

[0061] In some aspects, the baseband circuitry 1204 can include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access
30 network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 1204e of

the baseband circuitry 1204 can be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some aspects, the baseband circuitry can include one or more audio digital signal processor(s) (DSP) 1204f. The audio DSP(s) 1204f can include elements for compression/decompression and echo cancellation and can include other suitable processing elements in other aspects. Components of the baseband circuitry can be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some aspects. In some aspects, some or all of the constituent components of the baseband circuitry 1204 and the application circuitry 1202 can be implemented together such as, for example, on a system on a chip (SOC).

[0062] In some aspects, the baseband circuitry 1204 can provide for communication compatible with one or more radio technologies. For example, in some aspects, the baseband circuitry 1204 can support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Aspects in which the baseband circuitry 1204 is configured to support radio communications of more than one wireless protocol can be referred to as multi-mode baseband circuitry.

[0063] RF circuitry 1206 can enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various aspects, the RF circuitry 1206 can include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1206 can include a receive signal path which can include circuitry to down-convert RF signals received from the FEM circuitry 1208 and provide baseband signals to the baseband circuitry 1204. RF circuitry 1206 can also include a transmit signal path which can include circuitry to up-convert baseband signals provided by the baseband circuitry 1204 and provide RF output signals to the FEM circuitry 1208 for transmission.

[0064] In some aspects, the RF circuitry 1206 can include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 1206 can include mixer circuitry 1206a, amplifier circuitry 1206b and filter circuitry 1206c. The transmit signal path of the RF circuitry 1206 can include filter circuitry 1206c and mixer circuitry 1206a. RF circuitry 1206 can also include synthesizer circuitry 1206d for synthesizing a frequency for use by the mixer circuitry 1206a of the receive signal path and the transmit

signal path. In some aspects, the mixer circuitry 1206a of the receive signal path can be configured to down-convert RF signals received from the FEM circuitry 1208 based on the synthesized frequency provided by synthesizer circuitry 1206d. The amplifier circuitry 1206b can be configured to amplify the down-converted signals and the filter circuitry 1206c can be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals can be provided to the baseband circuitry 1204 for further processing. In some aspects, the output baseband signals can be zero-frequency baseband signals, although this is not a mandate. In some aspects, mixer circuitry 1206a of the receive signal path can comprise passive mixers, although the scope of the aspects is not limited in this respect.

[0065] In some aspects, the mixer circuitry 1206a of the transmit signal path can be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1206d to generate RF output signals for the FEM circuitry 1208. The baseband signals can be provided by the baseband circuitry 1204 and can be filtered by filter circuitry 1206c. The filter circuitry 1206c can include a low-pass filter (LPF), although the scope of the aspects is not limited in this respect.

[0066] In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can include two or more mixers and can be arranged for quadrature downconversion and/or upconversion respectively. In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can include two or more mixers and can be arranged for image rejection (e.g., Hartley image rejection). In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a can be arranged for direct downconversion and/or direct upconversion, respectively. In some aspects, the mixer circuitry 1206a of the receive signal path and the mixer circuitry 1206a of the transmit signal path can be configured for super-heterodyne operation.

[0067] In some aspects, the output baseband signals and the input baseband signals can be analog baseband signals, although the scope of the aspects is not limited in this respect. In some alternate aspects, the output baseband signals and the input baseband signals can be digital baseband signals. In these alternate aspects, the RF circuitry 1206 can include analog-to-digital converter (ADC) and digital-to-analog converter (DAC)

circuitry and the baseband circuitry 1204 can include a digital baseband interface to communicate with the RF circuitry 1206.

[0068] In some dual-mode embodiments, a separate radio IC circuitry can be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0069] In some embodiments, the synthesizer circuitry 1206d can be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers can be suitable. For example, synthesizer circuitry 1206d can be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0070] The synthesizer circuitry 1206d can be configured to synthesize an output frequency for use by the mixer circuitry 1206a of the RF circuitry 1206 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1206d can be a fractional $N/N+1$ synthesizer.

[0071] In some embodiments, frequency input can be provided by a voltage controlled oscillator (VCO), although that is not a mandate. Divider control input can be provided by either the baseband circuitry 1204 or the applications processor 1202 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) can be determined from a look-up table based on a channel indicated by the applications processor 1202.

[0072] Synthesizer circuitry 1206d of the RF circuitry 1206 can include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider can be a dual modulus divider (DMD) and the phase accumulator can be a digital phase accumulator (DPA). In some embodiments, the DMD can be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL can include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements can be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0073] In some embodiments, synthesizer circuitry 1206d can be configured to generate a

carrier frequency as the output frequency, while in other embodiments, the output frequency can be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency can be a LO frequency (fLO). In some embodiments, the RF circuitry 1206 can include an IQ/polar converter.

[0074] FEM circuitry 1208 can include a receive signal path which can include circuitry configured to operate on RF signals received from one or more antennas 1210, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1206 for further processing. FEM circuitry 1208 can also include a transmit signal path which can include circuitry configured to amplify signals for transmission provided by the RF circuitry 1206 for transmission by one or more of the one or more antennas 1210.

[0075] In some embodiments, the FEM circuitry 1208 can include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry can include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry can include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1206). The transmit signal path of the FEM circuitry 1208 can include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1206), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1210).

[0076] In some embodiments, the UE device 1800 can include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0077] FIG. 13 illustrates a diagram 1300 of a node 1310 (e.g., eNB and/or a Serving GPRS Support Node) and wireless device (e.g., UE) in accordance with an example. The node can include a base station (BS), a Node B (NB), an evolved Node B (eNB), a baseband unit (BBU), a remote radio head (RRH), a remote radio equipment (RRE), a remote radio unit (RRU), or a central processing module (CPM). In one aspect, the node can be a Serving GPRS Support Node. The node 1310 can include a node device 1312.

The node device 1312 or the node 1310 can be configured to communicate with the wireless device 1320. The node device 1312 can be configured to implement the technology described. The node device 1312 can include a processing module 1314 and a transceiver module 1316. In one aspect, the node device 1312 can include the transceiver module 1316 and the processing module 1314 forming a circuitry 1318 for the node 1310. In one aspect, the transceiver module 1316 and the processing module 1314 can form a circuitry of the node device 1312. The processing module 1314 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1316 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1316 can include a baseband processor.

[0078] The wireless device 1320 can include a transceiver module 1324 and a processing module 1322. The processing module 1322 can include one or more processors and memory. In one embodiment, the processing module 1322 can include one or more application processors. The transceiver module 1324 can include a transceiver and one or more processors and memory. In one embodiment, the transceiver module 1324 can include a baseband processor. The wireless device 1320 can be configured to implement the technology described. The node 1310 and the wireless devices 1320 can also include one or more storage mediums, such as the transceiver module 1316, 1324 and/or the processing module 1314, 1322.

[0079] As used herein, the term "circuitry" can refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some aspects, the circuitry can be implemented in, or functions associated with the circuitry can be implemented by, one or more software or firmware modules. In some aspects, circuitry can include logic, at least partially operable in hardware.

Examples

[0080] The following examples pertain to specific technology embodiments and point out specific features, elements, or steps that can be used or otherwise combined in achieving

such embodiments.

[0081] Example 1 can include an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to: exchange, with one or
5 more D2D UEs, sidelink control information (SCI) transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine physical resource allocation for SCI communication based on the exchange to identify selected SCI periods for the UE; process SCI for transmission to the one or more D2D UEs on the selected SCI periods; and process D2D UE SCI, received from the one or
10 more D2D UEs, at the UE on the selected SCI periods.

[0082] Example 2 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to use a dedicated SCI format to transmit control information.

[0083] Example 3 includes the apparatus of example 1 or 2, wherein the one or more
15 processors and memory are further configured to process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[0084] Example 4 includes the apparatus of example 1, wherein the one or more
20 processors and memory are further configured to process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.

[0085] Example 5 includes the apparatus of example 1 or 4, wherein the one or more processors and memory are further configured to process, for transmission during the
25 selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[0086] Example 6 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to use a higher layer control signaling
30 protocol to transmit control information.

[0087] Example 7 includes the apparatus of example 6, wherein the one or more processors and memory are further configured to encode and process the higher layer

control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel PSDCH.

[0088] Example 8 includes the apparatus of example 1 or 7, wherein the one or more processors and memory are further configured to include in a control message at least one
5 of acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI), precoding index, a rank, a target modulation and coding scheme (MCS), an index of a time resource pattern for transmission (T-RPT), a frequency allocation, a SCI resource index, or a combination thereof.

[0089] Example 9 includes the apparatus of example 1, wherein the one or more
10 processors and memory are further configured to include in a control message resource scheduling information for the one or more D2D UEs.

[0090] Example 10 includes the apparatus of example 1 or 9, wherein the one or more processors and memory are further configured to configure physical resources of logical cycles for transmitting data.

15 [0091] Example 11 includes the apparatus of example 9, wherein the logical cycles are a multiple or a fraction of an SCI period.

[0092] Example 12 includes the apparatus of example 1 or 9, wherein the one or more processors and memory are further configured to use a bitmap to identify the selected SCI periods to activate or deactivate an SCI period.

20 [0093] Example 13 includes the apparatus of example 12, wherein the one or more processors and memory are further configured to configure the physical resources with a SCI resource index and a time resource pattern for transmission (T-RPT) for the one or more D2D UEs.

[0094] Example 14 includes the apparatus of example 1, wherein the one or more
25 processors and memory are further configured to configure a logical transmission zone applied over an SCI resource pool and data resource pool configuration.

[0095] Example 15 includes the apparatus of example 1 or 14, wherein the one or more processors and memory are further configured to place a higher layer control signaling protocol in a physical sidelink broadcast channel (PSBCH), a master information block
30 (MIB), a system information block (SIB), or a UE-specific dedicated RRC signalling.

[0096] Example 16 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to orthogonalize data transmissions

between the UE and the one or more D2D UEs for SCI and data transmission.

[0097] Example 17 includes the apparatus of example 1 or 16, wherein the one or more processors and memory are further configured to select the physical resources for the SCI transmission and data transmission from a subset of physical resources that are orthogonal to an SCI resource and a time resource pattern for transmission (T-RPT) used by a first transmission of the UE.

[0098] Example 18 includes the apparatus of example 1, wherein the one or more processors and memory are further configured to set SCI formats by either setting a time resource pattern for transmission (T-RPT) index to a reserved value, or scrambling the SCI payload or cyclic redundant check (CRC) with a predefined sequence.

[0099] Example 19 includes the apparatus of example 1 or 18, wherein the one or more processors and memory are further configured to allocate a dedicated resource pool for an SCI format.

[00100] Example 20 includes the apparatus of example 1, wherein the apparatus includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, an application processor, a baseband processor, internal memory, a non-volatile memory port, and combinations thereof.

[00101] Example 21 includes at least one machine readable storage medium having instructions embodied thereon for control signaling for enhanced device-to-device (D2D) communication with a user equipment (UE) operating in mode-2, the instructions when executed perform the following: exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine physical resource allocation for SCI communication based on the exchange; process SCI for transmission to the one or more D2D UEs on a selected SCI period; and process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.

[00102] Example 22 includes the at least one machine readable storage medium of example 21, further comprising instructions which when executed performs the following: use a dedicated SCI format to transmit control information.

[00103] Example 23 includes the at least one machine readable storage medium example 21 or 22, further comprising instructions which when executed performs the following:

process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

- 5 [00104] Example 24 includes the at least one machine readable storage medium of example 21, further comprising instructions which when executed performs the following: process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.
- 10 [00105] Example 25 includes the at least one machine readable storage medium of example 21 or 24, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state
- 15 information (CSI), and a channel quality indicator (CQI).
- [00106] Example 26 includes the at least one machine readable storage medium of claim 21, further comprising instructions which when executed performs the following: use a higher layer control signaling protocol to transmit control information.
- [00107] Example 27 includes the at least one machine readable storage medium claim 21
- 20 or 26, further comprising instructions which when executed performs the following: encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel (PSDCH).
- [00108] Example 28 includes an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus
- 25 comprising one or more processors and memory configured to: process a blind sidelink control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information; process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH) according to the SCI transmission; and process, for transmission, to the second UE the
- 30 D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI). The broadcast data can be processed and the

control information can be broadcast using one or more of a baseband processor or an application processor.

[00109] Example 29 includes an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to: exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine physical resource allocation for SCI communication based on the exchange to identify selected SCI periods for the UE; process SCI for transmission to the one or more D2D UEs on the selected SCI periods; and process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.

[00110] Example 30 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to use a dedicated SCI format to transmit control information.

[00111] Example 31 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00112] Example 32 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.

[00113] Example 33 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00114] Example 34 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to use a higher layer control signaling protocol to transmit control information.

[00115] Example 35 includes the apparatus of example 34, wherein the one or more

processors and memory are further configured to encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel PSDCH.

- 5 [00116] Example 36 includes the apparatus of example 35, wherein the one or more processors and memory are further configured to include in a control message at least one of acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI), precoding index, a rank, a target modulation and coding scheme (MCS), an index of a time resource pattern for transmission (T-RPT), a frequency allocation, a SCI resource index, or a combination thereof.
- 10 [00117] Example 37 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to include in a control message resource scheduling information for the one or more D2D UEs.
- [00118] Example 38 includes the apparatus of example 37, wherein the one or more processors and memory are further configured to configure physical resources of logical
15 cycles for transmitting data.
- [00119] Example 39 includes the apparatus of example 38, wherein the logical cycles are a multiple or a fraction of an SCI period.
- [00120] Example 40 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to use a bitmap to identify the selected SCI
20 periods to activate or deactivate an SCI period.
- [00121] Example 41 includes the apparatus of example 40, wherein the one or more processors and memory are further configured to configure the physical resources with a SCI resource index and a time resource pattern for transmission (T-RPT) for the one or more D2D UEs.
- 25 [00122] Example 42 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to configure a logical transmission zone applied over an SCI resource pool and data resource pool configuration.
- [00123] Example 43 includes the apparatus of example 42, wherein the one or more processors and memory are further configured to place a higher layer control signaling
30 protocol in a physical sidelink broadcast channel (PSBCH), a master information block (MIB), a system information block (SIB), or a UE-specific dedicated RRC signalling.
- [00124] Example 44 includes the apparatus of example 29, wherein the one or more

processors and memory are further configured to orthogonalize data transmissions between the UE and the one or more D2D UEs for SCI and data transmission.

[00125] Example 45 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to select the physical resources for the SCI transmission and data transmission from a subset of physical resources that are orthogonal to an SCI resource and a time resource pattern for transmission (T-RPT) used by a first transmission of the UE.

[00126] Example 46 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to set SCI formats by either setting a time resource pattern for transmission (T-RPT) index to a reserved value, or scrambling the SCI payload or cyclic redundant check (CRC) with a predefined sequence.

[00127] Example 47 includes the apparatus of example 29, wherein the one or more processors and memory are further configured to allocate a dedicated resource pool for an SCI format.

[00128] Example 48 includes the apparatus of example 29, wherein the apparatus includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, an application processor, a baseband processor, internal memory, a non-volatile memory port, and combinations thereof.

[00129] Example 49 includes one or more transitory or non-transitory machine readable storage medium having instructions embodied thereon for control signaling for enhanced device-to-device (D2D) communication with a user equipment (UE) operating in mode-2, the instructions when executed perform the following: exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine physical resource allocation for SCI communication based on the exchange; process SCI for transmission to the one or more D2D UEs on a selected SCI period; and process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.

[00130] Example 50 includes the one or more transitory or non-transitory machine readable storage medium of example 49, further comprising instructions which when executed performs the following: use a dedicated SCI format to transmit control information.

[00131] Example 51 includes the one or more transitory or non-transitory machine readable storage medium of example 49, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes
5 at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00132] Example 52 includes the one or more transitory or non-transitory machine readable storage medium of example 49, further comprising instructions which when executed performs the following: process the SCI having an acknowledgment
10 (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.

[00133] Example 53 includes the one or more transitory or non-transitory machine readable storage medium example 49, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI
15 periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00134] Example 54 includes the one or more transitory or non-transitory machine readable storage medium example 49, further comprising instructions which when
20 executed performs the following: use a higher layer control signaling protocol to transmit control information.

[00135] Example 55 includes the one or more transitory or non-transitory machine readable storage medium of example 49, further comprising instructions which when executed performs the following: encode and process the higher layer control signaling in
25 a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel (PSDCH).

[00136] Example 56 includes an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to: process a blind sidelink
30 control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information; process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH)

according to the SCI transmission; and process, for transmission, to the second UE the D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI).

5 [00137] Example 57 includes an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to: exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine
10 physical resource allocation for SCI communication based on the exchange to identify selected SCI periods for the UE; process SCI for transmission to the one or more D2D UEs on the selected SCI periods; and process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.

[00138] Example 58 includes the apparatus of example 57, wherein the one or more
15 processors and memory are further configured to: use a dedicated SCI format to transmit control information; process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI); receive, from the one or more
20 D2D UEs the SCI having the ACK/NACK signal, the CSI, and the CQI; process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least the ACK/NACK signal, the CSI, or the CQI; or use a higher layer control signaling protocol to transmit control information.

[00139] Example 59 includes the apparatus of example 57 or 58, wherein the one or more
25 processors and memory are further configured to encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel PSDCH.

[00140] In Example 60, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the one or more processors and memory
30 are further configured to include in a control message at least one of acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI), precoding index, a rank, a target modulation

and coding scheme (MCS), an index of a time resource pattern for transmission (T-RPT), a frequency allocation, a SCI resource index, or a combination thereof.

[00141] In Example 61, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the one or more processors and memory
5 are further configured to: include in a control message resource scheduling information for the one or more D2D UEs; configure physical resources of logical cycles for transmitting data, wherein the logical cycles are a multiple or a fraction of an SCI period; use a bitmap to identify the selected SCI periods to activate or deactivate an SCI period; or configure the physical resources with a SCI resource index and a time resource pattern
10 for transmission (T-RPT) for the one or more D2D UEs.

[00142] In Example 62, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the one or more processors and memory are further configured to: configure a logical transmission zone applied over an SCI resource pool and data resource pool configuration; place a higher layer control signaling
15 protocol in a physical sidelink broadcast channel (PSBCH), a master information block (MIB), a system information block (SIB), or a UE-specific dedicated RRC signaling; or orthogonalize data transmissions between the UE and the one or more D2D UEs for SCI and data transmission.

[00143] In Example 63, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the one or more processors and memory
20 are further configured to select the physical resources for the SCI transmission and data transmission from a subset of physical resources that are orthogonal to an SCI resource and a time resource pattern for transmission (T-RPT) used by a first transmission of the UE.

[00144] In Example 64, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the one or more processors and memory are further configured to: set SCI formats by either setting a time resource pattern for transmission (T-RPT) index to a reserved value, or scrambling the SCI payload or cyclic
25 redundant check (CRC) with a predefined sequence; or allocate a dedicated resource pool
30 for an SCI format.

[00145] In Example 65, the subject matter of Example 57 or any of the Examples described herein may further include, wherein the apparatus includes at least one of an

antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, an application processor, a baseband processor, internal memory, a non-volatile memory port, and combinations thereof.

[00146] Example 66 includes one or more transitory or non-transitory machine readable storage medium having instructions embodied thereon for control signaling for enhanced device-to-device (D2D) communication with a user equipment (UE) operating in mode-2, the instructions when executed perform the following: exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception; determine physical resource allocation for SCI communication based on the exchange; process SCI for transmission to the one or more D2D UEs on a selected SCI period; and process the SCI, received from the one or more D2D UEs, at the UE on the selected SCI period.

[00147] Example 67 includes the one or more transitory or non-transitory machine readable storage medium of example 66, further comprising instructions which when executed performs the following: use a dedicated SCI format to transmit control information; process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI); and use a higher layer control signaling protocol to transmit control information.

[00148] Example 68 includes the one or more transitory or non-transitory machine readable storage medium of example 66 or 67, further comprising instructions which when executed performs the following: process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.

[00149] In Example 69, the subject matter of Example 66 or any of the Examples described herein may further include, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00150] In Example 70, the subject matter of Example 66 or any of the Examples described herein may further include, further comprising instructions which when executed performs the following: encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel (PSDCH).

[00151] Example 71 includes an apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to: process a blind sidelink control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information; process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH) according to the SCI transmission; and process, for transmission, to the second UE the D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI).

[00152] Example 72 includes a device for controlling signaling for enhanced device-to-device (D2D) communication of a user equipment (UE) operating in mode-2, the device comprising: means for exchanging, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception; means for determining physical resource allocation for SCI communication based on the exchange; means for transmitting SCI to the one or more D2D UEs on a selected SCI periods; and means for receiving from the one or more D2D UEs the SCI at the UE on the selected SCI periods.

[00153] Example 73 includes the device of example 72, further comprising means for using a dedicated SCI format to transmit control information.

[00154] Example 74 includes the device of example 72, further comprising means for transmitting during the selected SCI periods to the one or more D2D UEs control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00155] Example 75 includes the device of example 72, further comprising means for

receiving, from the one or more D2D UEs the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00156] Example 76 includes the device of example 72, further comprising means for transmitting during the selected SCI periods to the one or more D2D UEs control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).

[00157] Example 77 includes the device of example 72, further comprising means for using a higher layer control signaling protocol to transmit control information.

[00158] Example 78 includes the device of example 72, further comprising means for encoding and transmitting the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel (PSDCH).

[00159] As used herein, the term "circuitry" can refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some aspects, the circuitry can be implemented in, or functions associated with the circuitry can be implemented by, one or more software or firmware modules. In some aspects, circuitry can include logic, at least partially operable in hardware.

[00160] Various techniques, or certain aspects or portions thereof, can take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, compact disc-read-only memory (CD-ROMs), hard drives, non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. Circuitry can include hardware, firmware, program code, executable code, computer instructions, and/or software. A non-transitory computer readable storage medium can be a computer readable storage medium that does not include signal. In the case of program code execution on programmable computers, the computing device can include a processor, a storage medium readable by the processor (including volatile and non-volatile memory

and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements can be a random-access memory (RAM), erasable programmable read only memory (EPROM), flash drive, optical drive, magnetic hard drive, solid state drive, or other medium for storing electronic data. The node and wireless device can also include a transceiver module (i.e., transceiver), a counter module (i.e., counter), a processing module (i.e., processor), and/or a clock module (i.e., clock) or timer module (i.e., timer). One or more programs that can implement or utilize the various techniques described herein can use an application programming interface (API), reusable controls, and the like. Such programs can be implemented in a high level procedural or object oriented programming language to communicate with a computer system. However, the program(s) can be implemented in assembly or machine language, if desired. In any case, the language can be a compiled or interpreted language, and combined with hardware implementations.

[00161] As used herein, the term processor can include general purpose processors, specialized processors such as VLSI, FPGAs, or other types of specialized processors, as well as base band processors used in transceivers to send, receive, and process wireless communications.

[00162] It should be understood that many of the functional units described in this specification have been labeled as modules, in order to more particularly emphasize their implementation independence. For example, a module can be implemented as a hardware circuit comprising custom very-large-scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module can also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices or the like.

[00163] Modules can also be implemented in software for execution by various types of processors. An identified module of executable code can, for instance, comprise one or more physical or logical blocks of computer instructions, which can, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module may not be physically located together, but can comprise disparate instructions stored in different locations which, when joined logically together, comprise the module and achieve the stated purpose for the module.

[00164] Indeed, a module of executable code can be a single instruction, or many instructions, and can even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data can be identified and illustrated herein within modules, and can be embodied in any suitable form and organized within any suitable type of data structure. The operational data can be collected as a single data set, or can be distributed over different locations including over different storage devices, and can exist, at least partially, merely as electronic signals on a system or network. The modules can be passive or active, including agents operable to perform desired functions.

[00165] Reference throughout this specification to "an example" or "exemplary" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment of the present technology. Thus, appearances of the phrases "in an example" or the word "exemplary" in various places throughout this specification are not necessarily all referring to the same embodiment.

[00166] As used herein, a plurality of items, structural elements, compositional elements, and/or materials can be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present technology can be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as defacto equivalents of one another, but are to be considered as separate and autonomous representations of the present technology .

[00167] Furthermore, the described features, structures, or characteristics can be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of layouts, distances, network examples, etc., to provide a thorough understanding of embodiments of the technology .

One skilled in the relevant art will recognize, however, that the technology can be practiced without one or more of the specific details, or with other methods, components, layouts, etc. In other instances, well-known structures, materials, or operations are not

shown or described in detail to avoid obscuring aspects of the technology .

[00168] While the forgoing examples are illustrative of the principles of the present technology in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation
5 can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the technology . Accordingly, it is not intended that the technology be limited, except as by the claims set forth below.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to:
5 exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources to negotiate physical resources for bi-directional SCI transmission and SCI reception;
determine physical resource allocation for SCI communication based
10 on the exchange to identify selected SCI periods for the UE;
process SCI for transmission to the one or more D2D UEs on the selected SCI periods; and
process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.
15
2. The apparatus of claim 1, wherein the one or more processors and memory are further configured to use a dedicated SCI format to transmit control information.
- 20 3. The apparatus of claim 1 or 2, wherein the one or more processors and memory are further configured to process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality
25 indicator (CQI).
4. The apparatus of claim 1, wherein the one or more processors and memory are further configured to process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality
30 indicator (CQI) that is received from the one or more D2D UEs.

5. The apparatus of claim 1 or 4, wherein the one or more processors and memory are further configured to process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).
6. The apparatus of claim 1, wherein the one or more processors and memory are further configured to use a higher layer control signaling protocol to transmit control information.
7. The apparatus of claim 6, wherein the one or more processors and memory are further configured to encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel PSDCH.
8. The apparatus of claim 1 or 7, wherein the one or more processors and memory are further configured to include in a control message at least one of acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI), precoding index, a rank, a target modulation and coding scheme (MCS), an index of a time resource pattern for transmission (T-RPT), a frequency allocation, a SCI resource index, or a combination thereof
9. The apparatus of claim 1, wherein the one or more processors and memory are further configured to include in a control message resource scheduling information for the one or more D2D UEs.
10. The apparatus of claim 1 or 9, wherein the one or more processors and memory are further configured to configure physical resources of logical cycles for transmitting data.

11. The apparatus of claim 9, wherein the logical cycles are a multiple or a fraction of an SCI period.
12. The apparatus of claim 1 or 9, wherein the one or more processors and memory are further configured to use a bitmap to identify the selected SCI periods to activate or deactivate an SCI period.
13. The apparatus of claim 12, wherein the one or more processors and memory are further configured to configure the physical resources with a SCI resource index and a time resource pattern for transmission (T-RPT) for the one or more D2D UEs.
14. The apparatus of claim 1, wherein the one or more processors and memory are further configured to configure a logical transmission zone applied over an SCI resource pool and data resource pool configuration.
15. The apparatus of claim 1 or 14, wherein the one or more processors and memory are further configured to place a higher layer control signaling protocol in a physical sidelink broadcast channel (PSBCH), a master information block (MIB), a system information block (SIB), or a UE-specific dedicated RRC signalling.
16. The apparatus of claim 1, wherein the one or more processors and memory are further configured to orthogonalize data transmissions between the UE and the one or more D2D UEs for SCI and data transmission.
17. The apparatus of claim 1 or 16, wherein the one or more processors and memory are further configured to select the physical resources for the SCI transmission and data transmission from a subset of physical resources that are orthogonal to an SCI resource and a time resource pattern for transmission (T-RPT) used by a first transmission of the UE.

18. The apparatus of claim 1, wherein the one or more processors and memory are further configured to set SCI formats by either setting a time resource pattern for transmission (T-RPT) index to a reserved value, or scrambling the SCI payload or cyclic redundant check (CRC) with a predefined sequence.
- 5
19. The apparatus of claim 1 or 18, wherein the one or more processors and memory are further configured to allocate a dedicated resource pool for an SCI format.
- 10
20. The apparatus of claim 1, wherein the apparatus includes at least one of an antenna, a touch sensitive display screen, a speaker, a microphone, a graphics processor, an application processor, a baseband processor, internal memory, a non-volatile memory port, and combinations thereof.
- 15
21. A least one machine readable storage medium having instructions embodied thereon for control signaling for enhanced device-to-device (D2D) communication with a user equipment (UE) operating in mode-2, the instructions when executed perform the following:
- 20
- exchange, with one or more D2D UEs, sidelink control information (SCI) transmission resources using a bitmap to identify SCI periods to negotiate physical resources for bi-directional SCI transmission and SCI reception;
- determine physical resource allocation for SCI communication based on the exchange;
- 25
- process SCI for transmission to the one or more D2D UEs on a selected SCI period; and
- process D2D UE SCI, received from the one or more D2D UEs, at the UE on the selected SCI periods.
- 30
22. The at least one machine readable storage medium of claim 21, further comprising instructions which when executed performs the following: use a dedicated SCI format to transmit control information.

23. The at least one machine readable storage medium of claim 21 or 22, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).
24. The at least one machine readable storage medium of claim 21, further comprising instructions which when executed performs the following: process the SCI having an acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI) that is received from the one or more D2D UEs.
25. The at least one machine readable storage medium of claim 21 or 24, further comprising instructions which when executed performs the following: process, for transmission during the selected SCI periods to the one or more D2D UEs, control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK) signal, channel state information (CSI), and a channel quality indicator (CQI).
26. The at least one machine readable storage medium of claim 21, further comprising instructions which when executed performs the following: use a higher layer control signaling protocol to transmit control information.
27. The at least one machine readable storage medium of claim 21 or 26, further comprising instructions which when executed performs the following: encode and process the higher layer control signaling in a physical sidelink shared channel (PSSCH) or a physical sidelink discovery channel (PSDCH).

28. An apparatus of a user equipment (UE), the UE configured for control signaling for enhanced device-to-device (D2D) communication, the apparatus comprising one or more processors and memory configured to:
- 5 process a blind sidelink control information (SCI) transmission, received from a second UE, in a physical sidelink control channel (PSCCH) having D2D control information;
- process broadcast data, received from the second UE, in a physical sidelink shared channel (PSSCH) according to the SCI transmission; and
- 10 process, for transmission, to the second UE the D2D control information having feedback that includes at least an acknowledgment/negative acknowledgment (ACK/NACK), channel state information (CSI), and a channel quality indicator (CQI).
29. The apparatus of claim 28, wherein the broadcast data is processed and the
- 15 control information is broadcast using one or more of a baseband processor or an application processor.

1/13

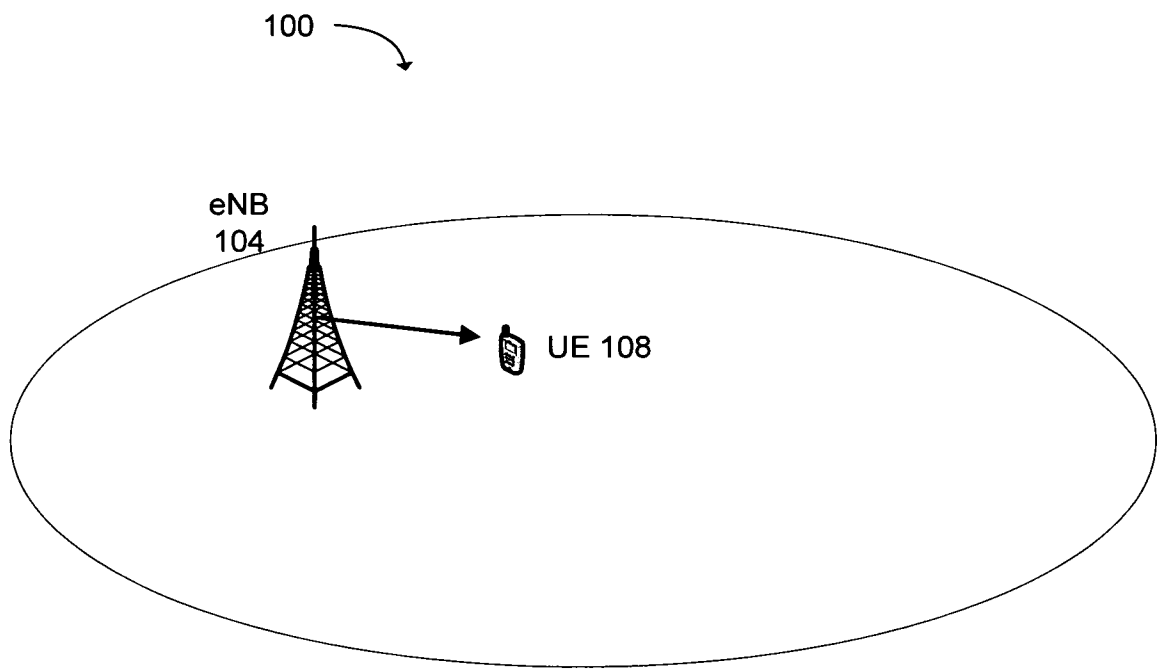


FIG. 1

200

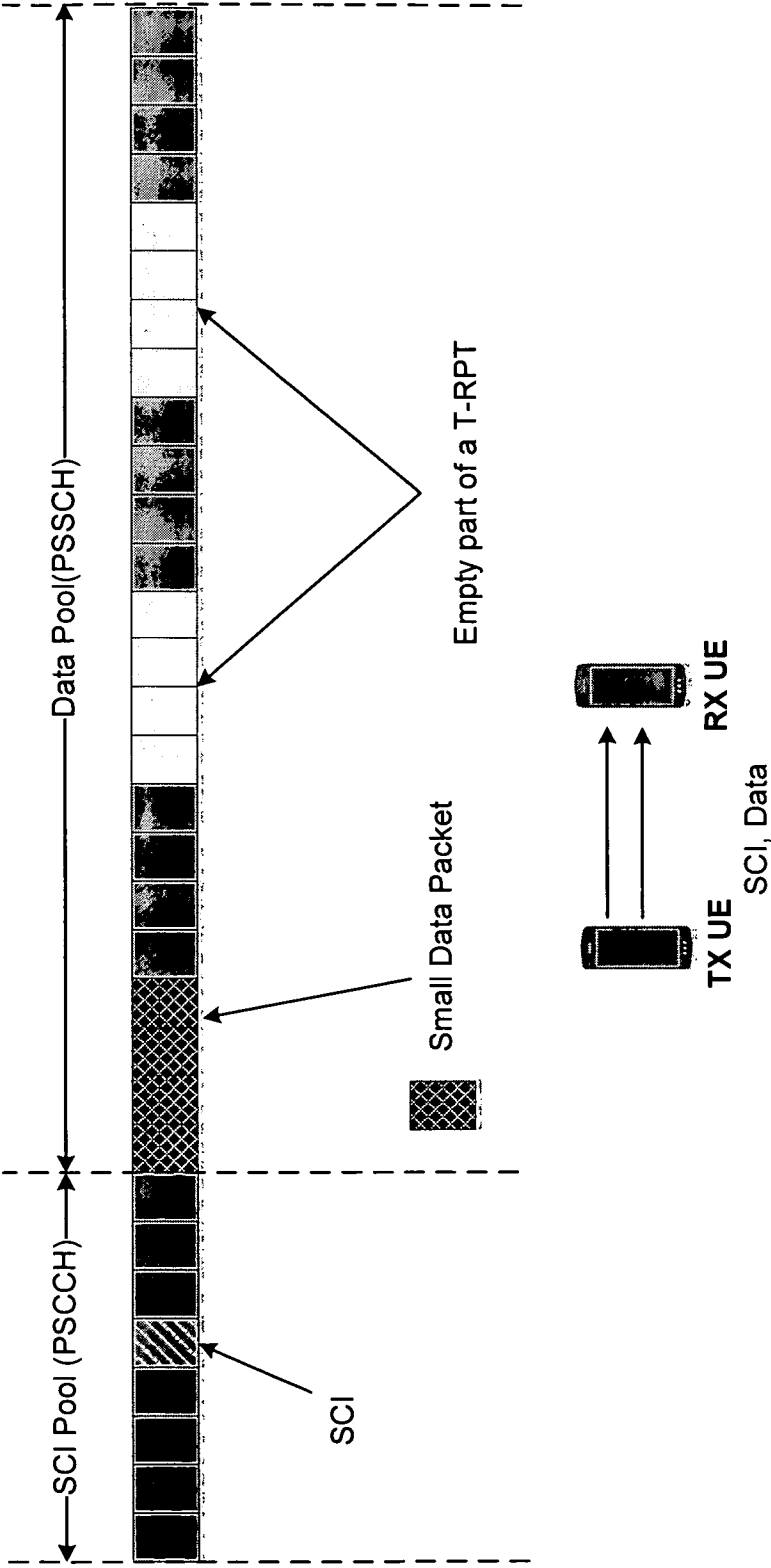


FIG. 2

300

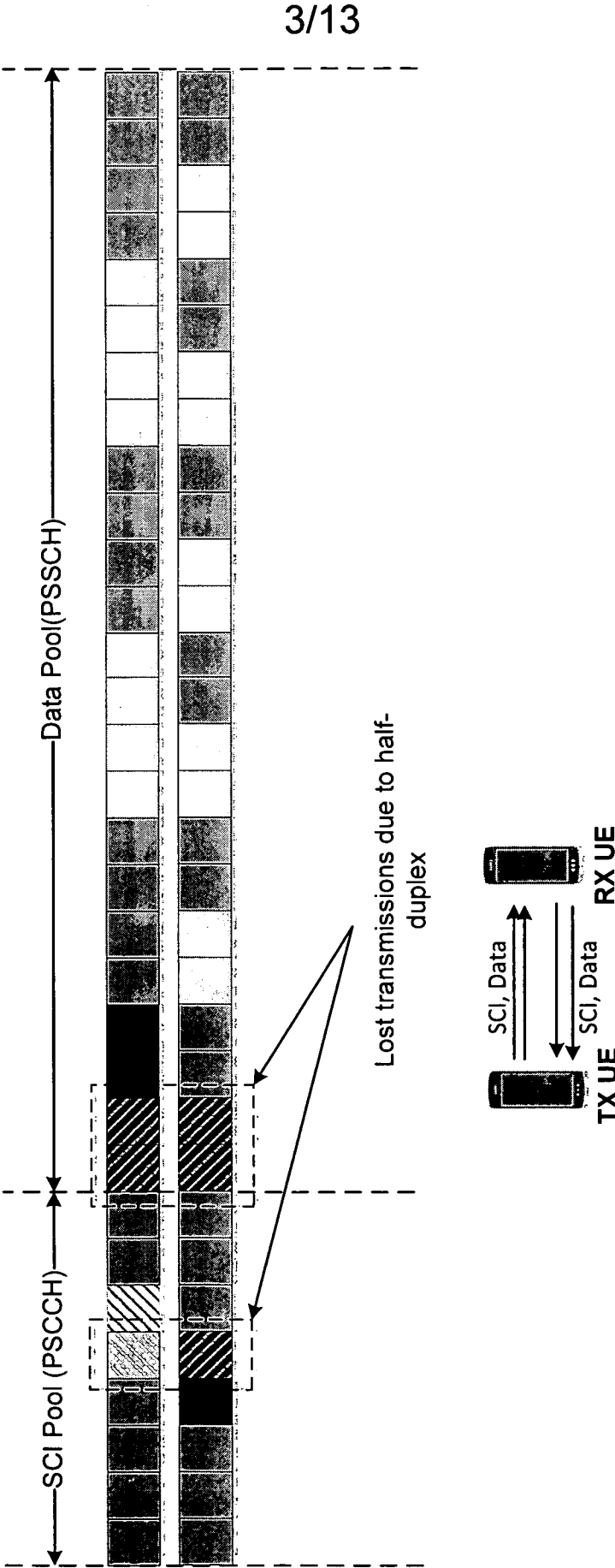


FIG. 3

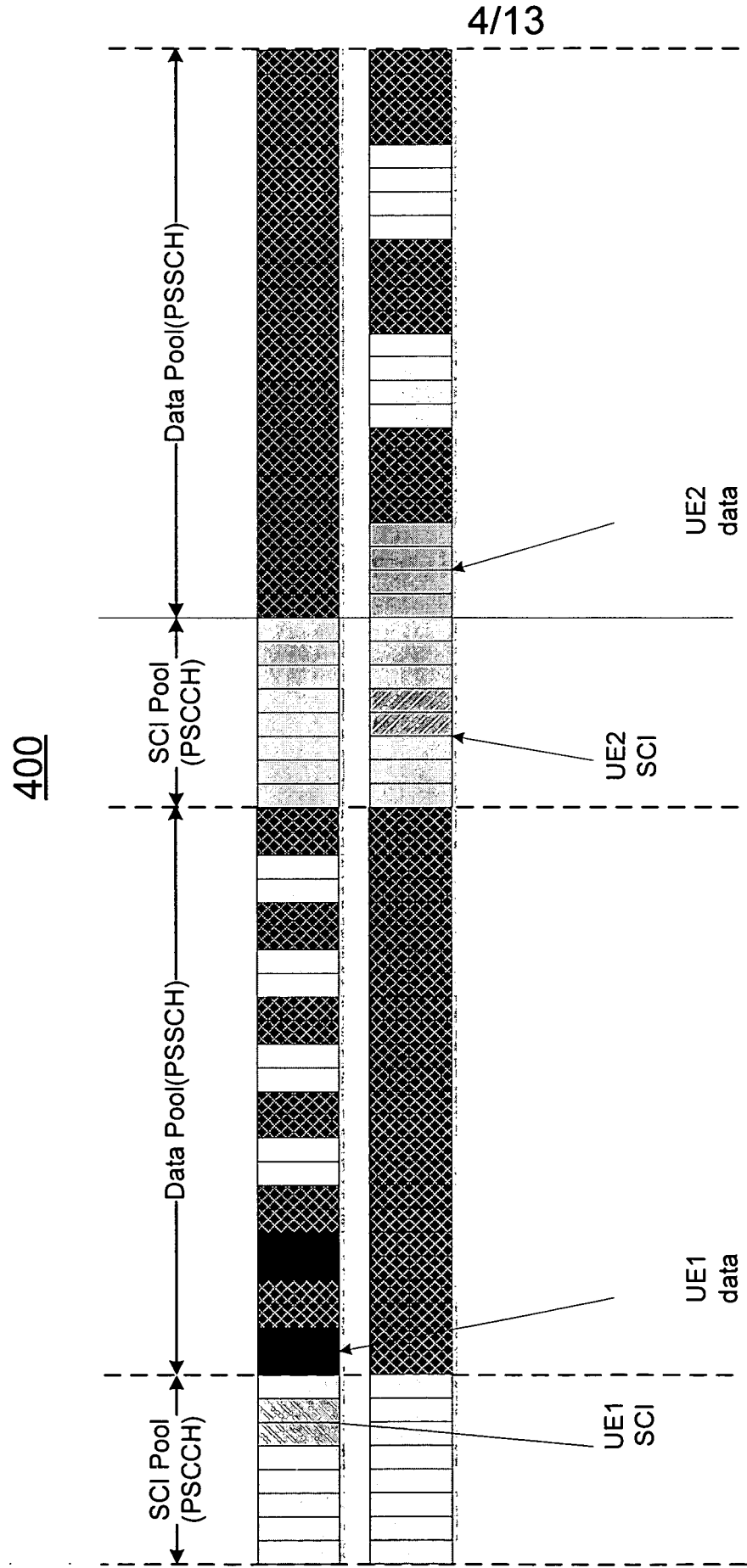


FIG. 4

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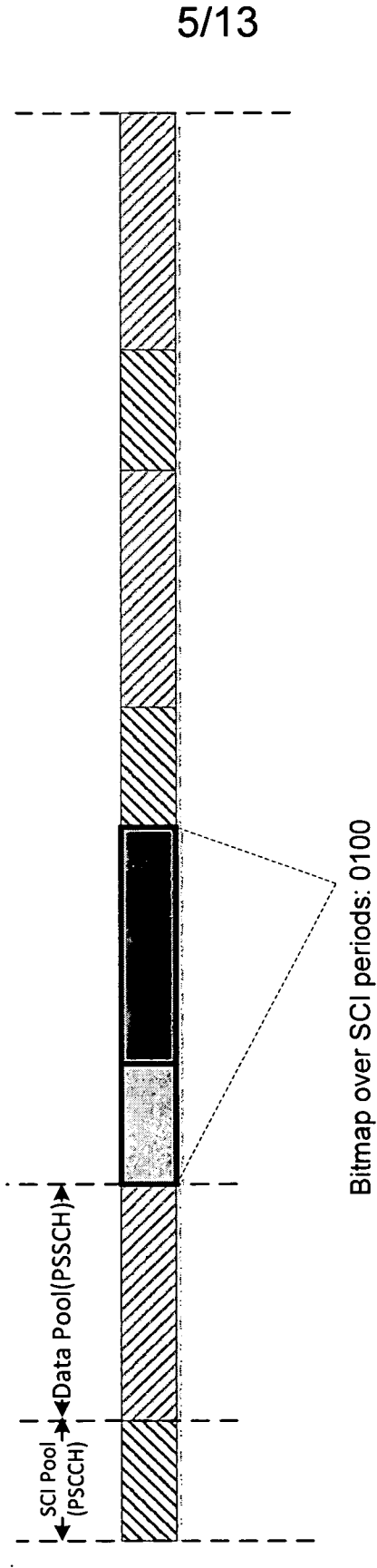


FIG. 5

600

6/13

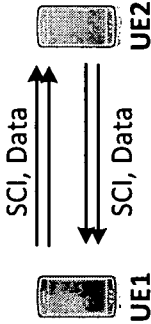
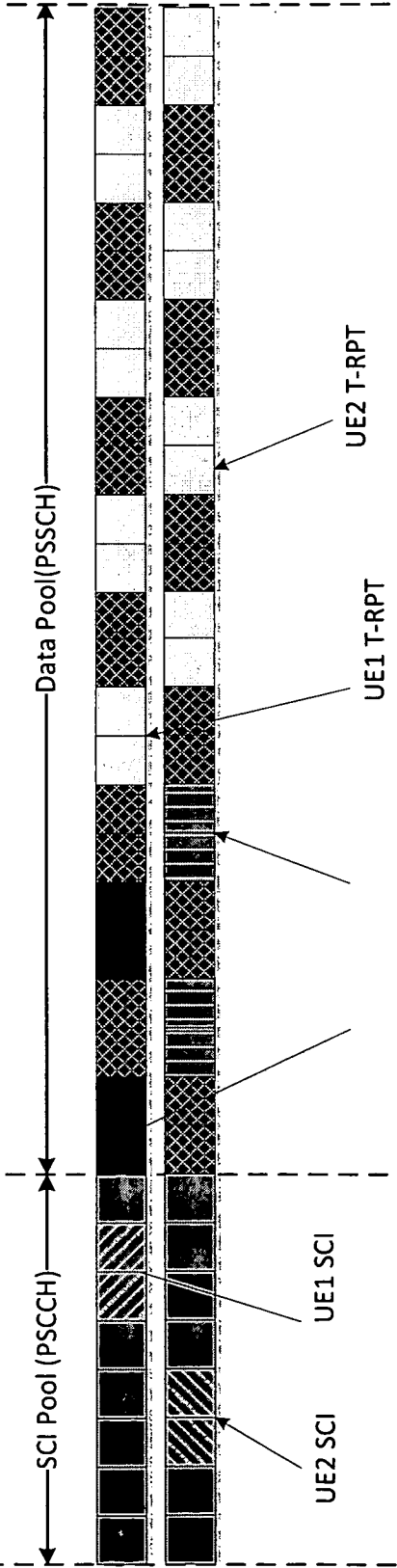


FIG. 6

7/13

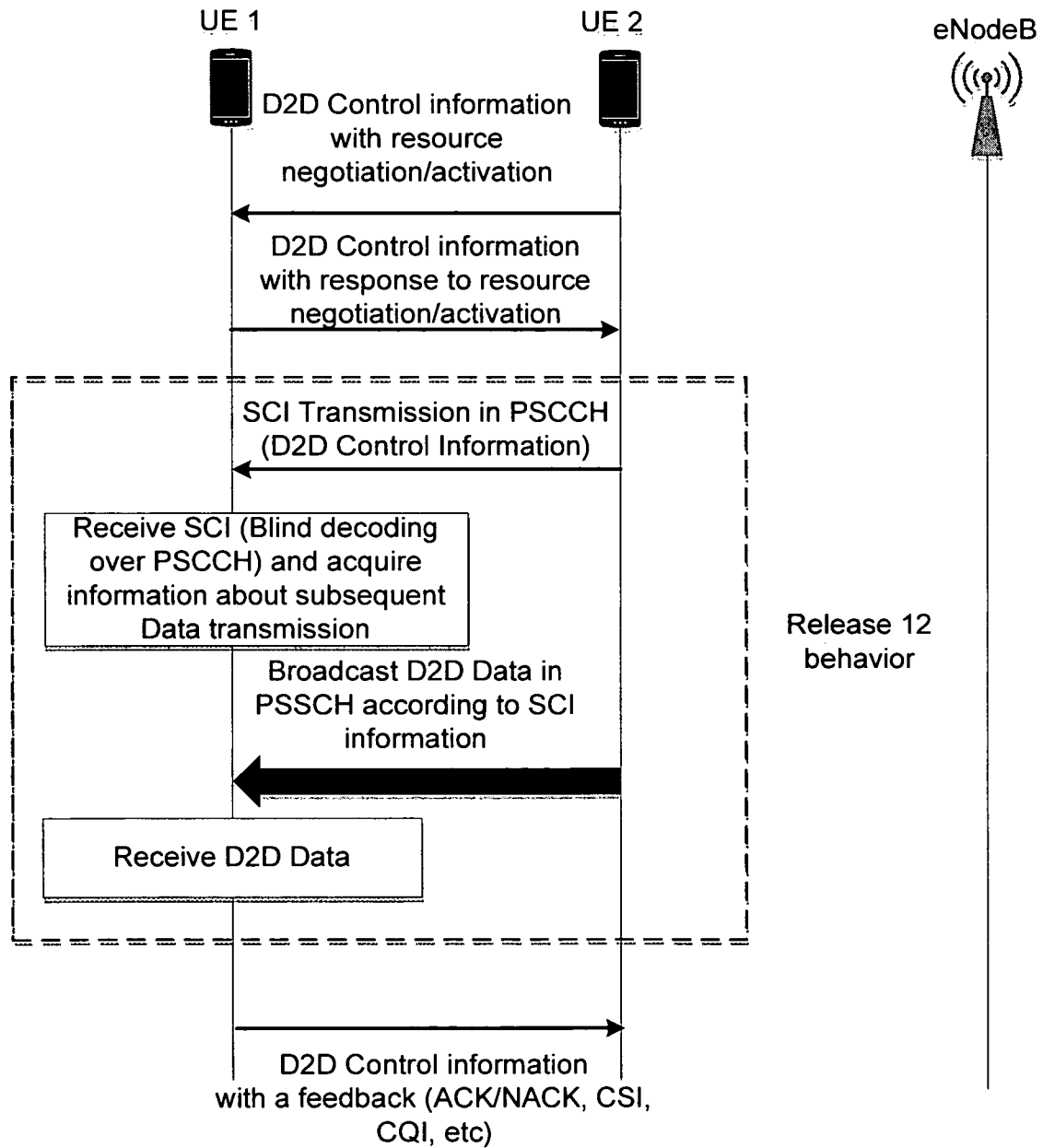
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FIG. 7

8/13

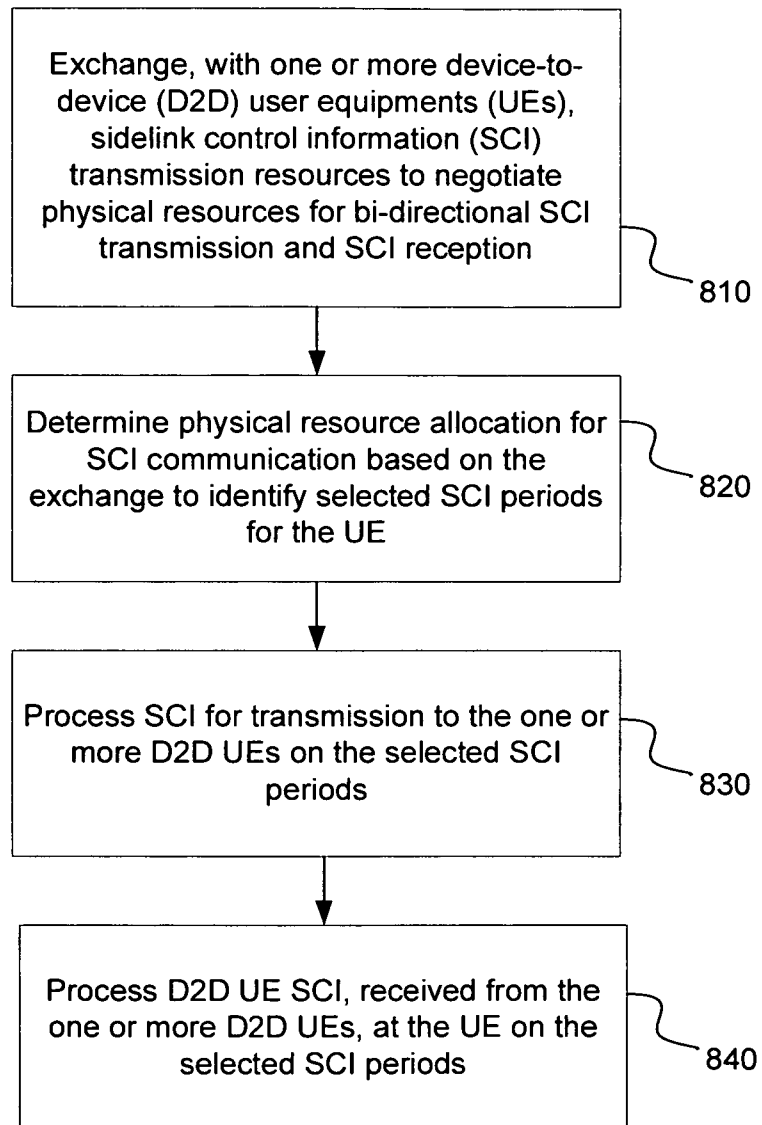
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FIG. 8

9/13

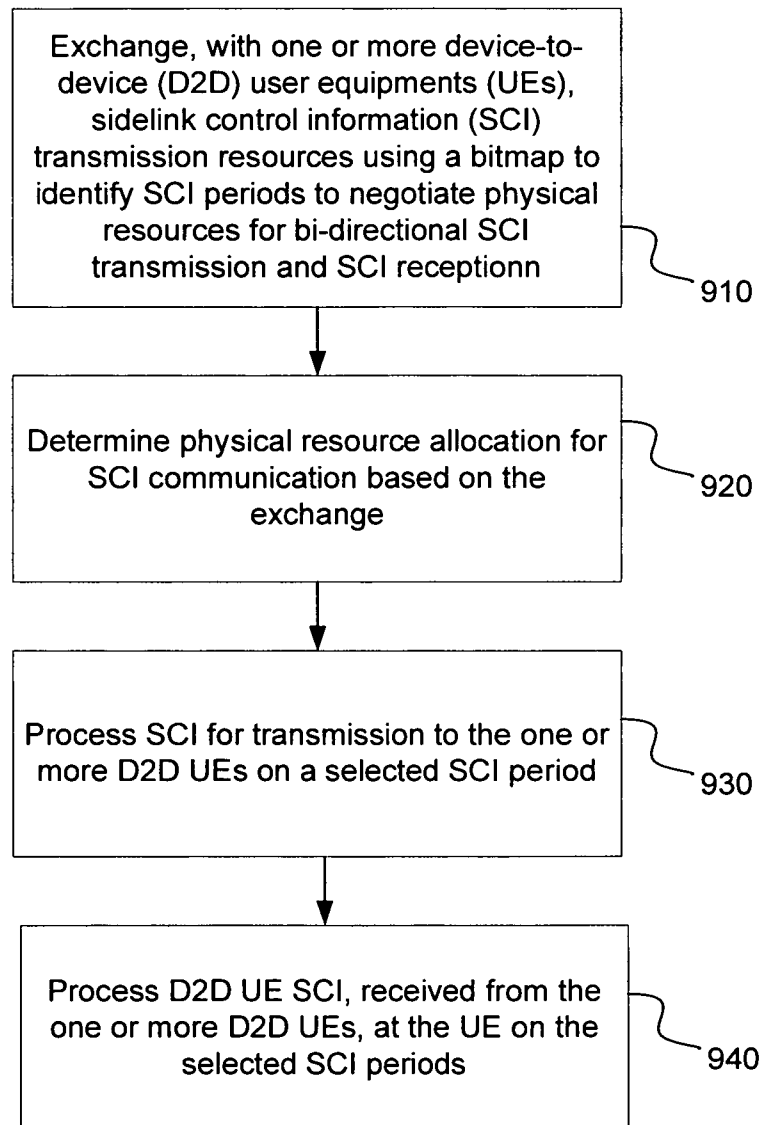
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FIG. 9

10/13

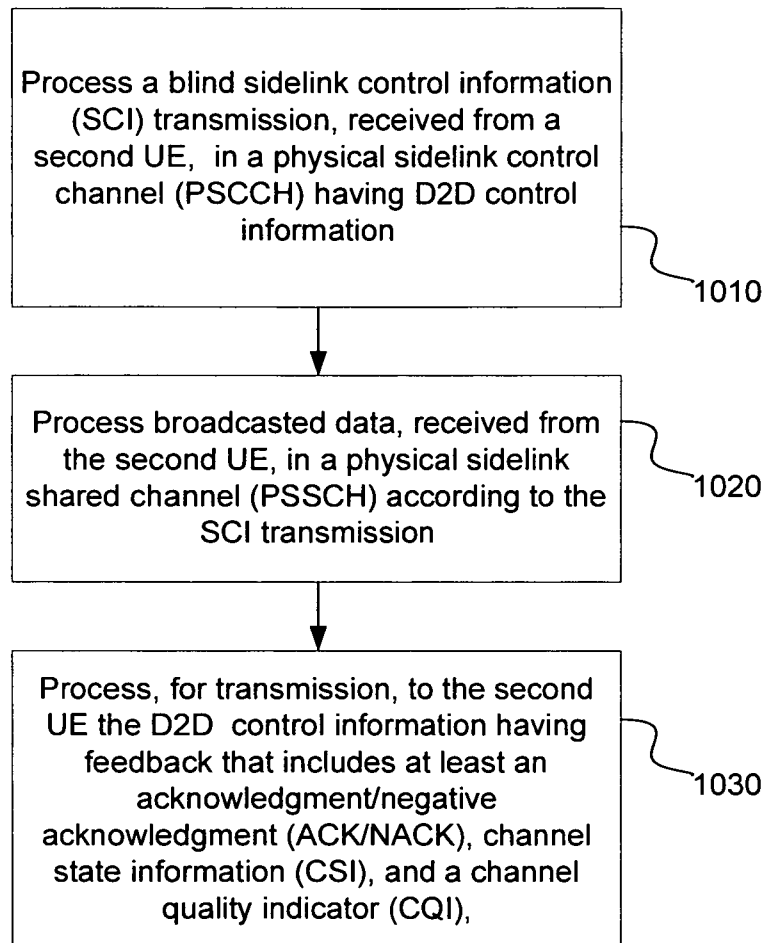
1000

FIG. 10

11/13

1100

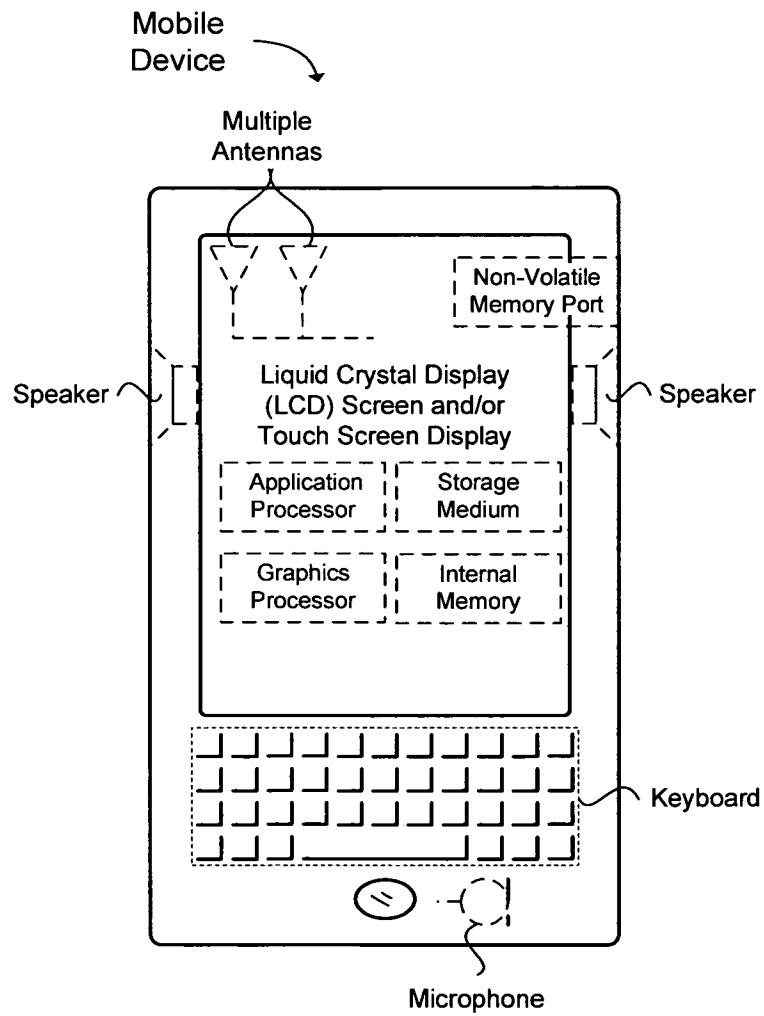


FIG. 11

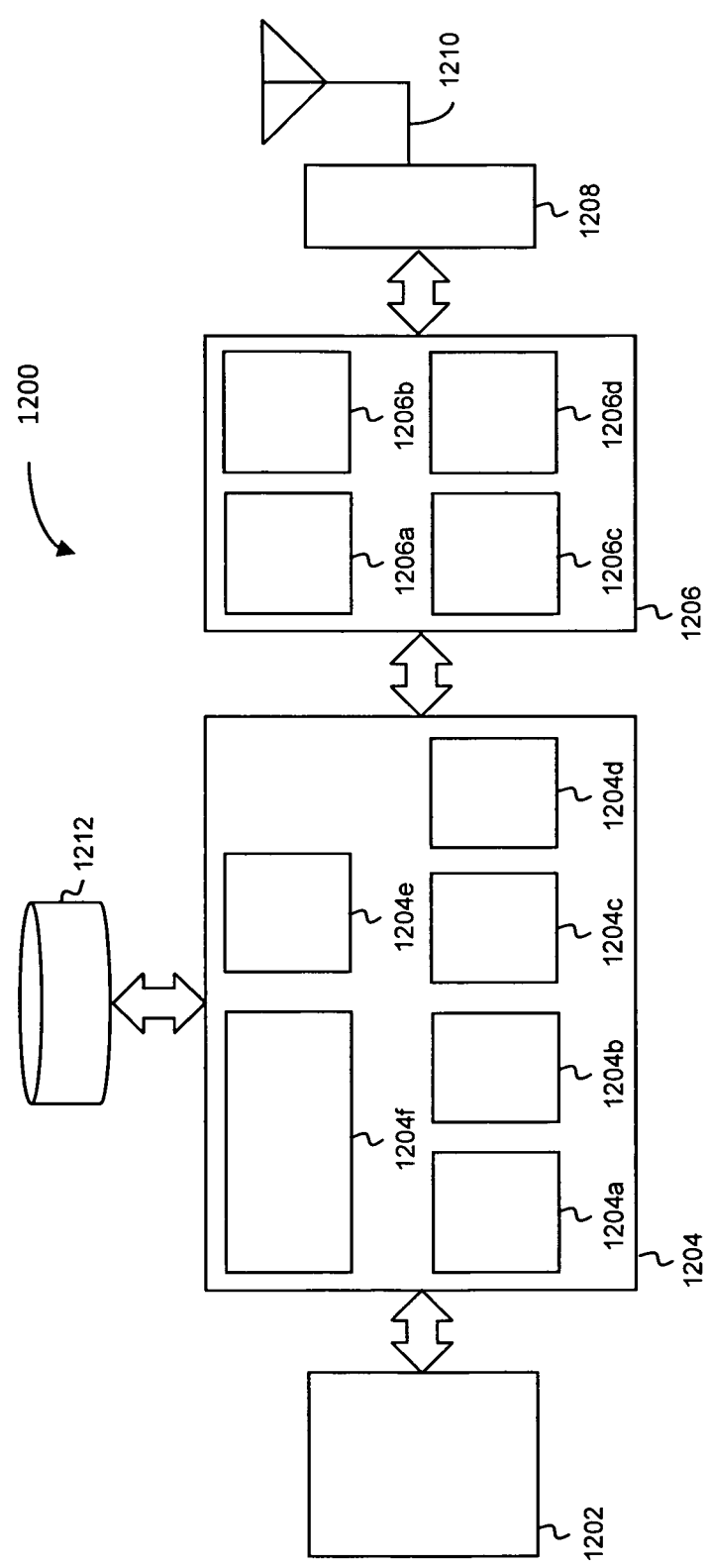


FIG. 12

13/13

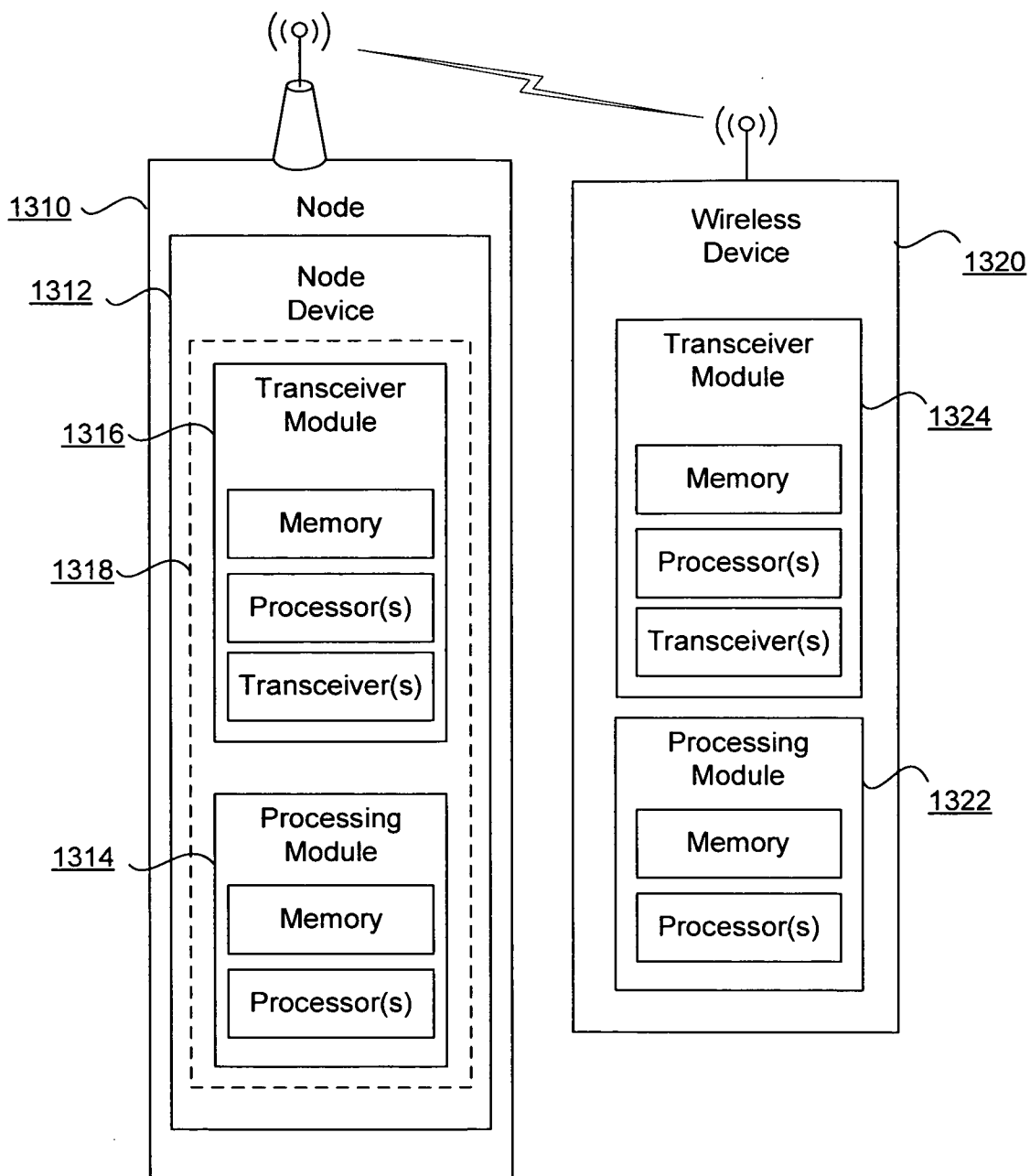
1300

FIG. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/000435

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W76/02

ADD. H04W72/04

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	WO 2015/170866 A1 (LG ELECTRONICS INC [KR]) 12 November 2015 (2015-11-12) paragraphs [0004] - [0007], [0080], [0081], [0088] - [0094], [0098]; figures 8, 10-12	1-29
X	US 2014/241262 A1 (NOVAK ROBERT [CA] ET AL) 28 August 2014 (2014-08-28) paragraphs [0049], [0084] - [0093]; figures 4a,4b,5b,7 ----- -/--	1-29



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

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PCT/US2015/000435

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