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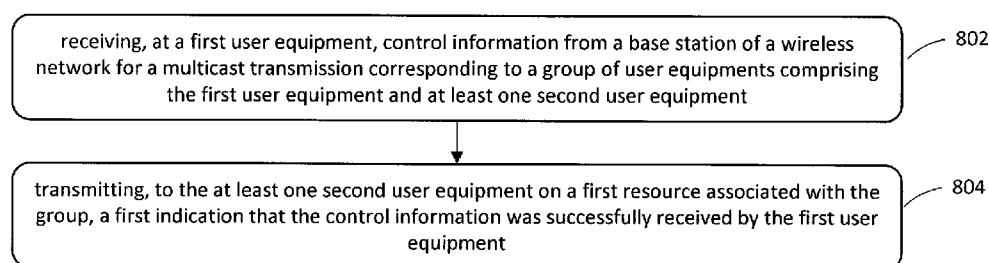


Fig. 8

(57) Abstract: According to an example embodiment a method is provided including receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

FEEDBACK FOR DOWNLINK MULTICAST BASED ON INTER-USER COOPERATION

5 TECHNICAL FIELD

[0001] This invention relates generally to wireless networks and, more specifically, relates to feedback for multicast communications.

BACKGROUND

10 [0002] This section is intended to provide a background or context to the invention disclosed below. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise explicitly indicated herein, what is described in this section is not prior art to the description in this application and is not admitted to be
15 prior art by inclusion in this section. Abbreviations that may be found in the specification and/or the drawing figures are defined below, after the main part of the detailed description section.

[0003] The next generation of wireless network is typically referred to as 5G. One of the most important services in 5G is V2X (vehicle-to-everything) due to its requirement
20 on high reliability and low latency. According to 3GPP TR 36.885, V2X can be divided into V2V, V2P and V2I/N services. V2V is a proximity-based service and is similar to D2D, as defined in 3GPP R-12, in such a way that V2V can reuse the sidelink defined in D2D for direct communications between neighboring vehicles that use the physical sidelink control channel (PSCCH) and the physical sidelink shared channel (PSSCH)
25 for scheduling assignment (SA) and data transmission, respectively. In these situations, a user equipment (UE) acquires information of time and frequency resource locations and modulation and coding scheme (MCS) after decoding PSCCH, then decodes PSSCH for data. However, due to distinct features of V2V (e.g. uncertainty of packet size and periodicity, high mobility and density of users, as well as strict requirement on
30 latency and reliability) more enhancements are required for the resource allocation mechanism, physical layer structure and uplink/downlink transmission procedures.

BRIEF SUMMARY

[0004] This section is intended to include examples and is not intended to be limiting.

[0005] An example of an apparatus includes one or more processors and one or more memories including computer program code. The one or more memories and the computer program code are configured to, with the one or more processors, cause the apparatus to perform at least the following: receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

[0006] In another example of an embodiment, an apparatus comprises means for receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and means for transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment

[0007] An example of a method includes receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

[0008] An additional example of an embodiment includes a computer program, comprising code for performing the method of the previous paragraph, when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product comprising a

computer-readable medium bearing computer program code embodied therein for use with a computer.

[0009] Another example of an apparatus includes one or more processors and one or more memories including computer program code. The one or more memories and the computer program code are configured to, with the one or more processors, cause the apparatus to perform at least the following: receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and determining that the control information was not successfully received at the second user equipment based on the first indication; and transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission

[0010] In another example of an embodiment, an apparatus comprises means for receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and means for determining that the control information was not successfully received at the second user equipment based on the first indication; and means for transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission

[0011] Another example of a method includes receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is

received on a first resource associated with the group; and determining that the control information was not successfully received at the second user equipment based on the first indication; and transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission

- 5 **[0012]** An additional example of an embodiment includes a computer program, comprising code for performing the method of the previous paragraph, when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use
10 with a computer.

- [0013]** Another example of an apparatus includes one or more processors and one or more memories including computer program code. The one or more memories and the computer program code are configured to, with the one or more processors, cause the apparatus to perform at least the following: allocating, by a base station, at least a first
15 resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to the multicast transmission was successfully received, and wherein the second resource is used to for
20 communicating a second indication between the group of user equipments of whether the multicast transmission was successfully received; receiving, at the base station, the feedback on a third resource shared by the group of user equipments; and determining whether to retransmit the multi-cast transmission to the group of user equipments based on the feedback.

- 25 **[0014]** In another example of an embodiment, an apparatus comprises means for allocating, by a base station, at least a first resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to
30 the multicast transmission was successfully received, and wherein the second resource is used to for communicating a second indication between the group of user equipments

of whether the multicast transmission was successfully received; means for receiving, at the base station, the feedback on a third resource shared by the group of user equipments; and means for determining whether to retransmit the multi-cast transmission to the group of user equipments based on the feedback.

- 5 [0015] Another example of a method includes allocating, by a base station, at least a first resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to the multicast transmission
- 10 was successfully received, and wherein the second resource is used to for communicating a second indication between the group of user equipments of whether the multicast transmission was successfully received; receiving, at the base station, the feedback on a third resource shared by the group of user equipments; and determining whether to retransmit the multi-cast transmission to the group of user equipments based
- 15 on the feedback

- [0016] An additional example of an embodiment includes a computer program, comprising code for performing the method of the previous paragraph, when the computer program is run on a processor. The computer program according to this paragraph, wherein the computer program is a computer program product comprising a
- 20 computer-readable medium bearing computer program code embodied therein for use with a computer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the attached Drawing Figures:

- 25 [0018] FIG. 1 is a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced;

[0019] FIG. 2 is a simplified diagram illustrating an example V2X multicast scenario in accordance with exemplary embodiments;

[0020] FIG. 3 is a simplified diagram illustrating an example V2X multicast scenario with inter-user cooperation based feedback in accordance with exemplary embodiments;

5 [0021] FIG. 4 is an example signaling diagram for inter-user cooperation based feedback mechanism in accordance with exemplary embodiments;

[0022] FIG. 5 is a logic flow diagram showing the behavior of a UE in response to PDCCH reception when no specific information is beared on a resource (R1) in accordance with exemplary embodiments;

10 [0023] FIG. 6 is a logic flow diagram showing the behavior of a UE in response to PDCCH reception when specific information is beared on a resource (R1) in accordance with exemplary embodiments;

[0024] FIG. 7 is a logic flow diagram that presents UE behavior in response to PDSCH reception in accordance with exemplary embodiments; and

15 [0025] FIGS. 8-10 are a logic flow diagrams for feedback for downlink multicast based on inter-user cooperation, and illustrate the operation of exemplary methods, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments.

20 DETAILED DESCRIPTION OF THE DRAWINGS

[0026] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. All of the embodiments described in this Detailed Description are exemplary embodiments
25 provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention which is defined by the claims.

[0027] Although the description refers to some LTE terms, this should not be seen as limiting, and the embodiments described herein are equally applicable to other wireless networks, such as 5G wireless network for example.

[0028] Currently, MBSFN and SC-PTM are assumed to support multicast delivery. In particular, SC-PTM provides multicast services over a single cell and uses a group-RNTI on PDCCH and PDSCH in regular LTE unicast subframes, which makes dynamic scheduling possible. Therefore, compared with MBSFN (which uses a semi-dynamic resource) SC-PTM is a more flexible way to provide multicast services in a single cell. HARQ feedback is not currently supported in SC-PTM since conventional multicast services have little requirements regarding reliability. However, the reliability requirement in V2X is strict because it provides services concerned with public safety. Therefore, the feedback mechanism for multicast needs to be considered in V2X for reliability enhancement.

[0029] 3GPP TR 36.890 has decided that SC-PTM with feedback can provide better spectral efficiency. Furthermore, it is recommended in 3GPP TR 36.885 that HARQ feedback for downlink multicast enhancement be supported. The following two options are possibilities for resource allocation for feedback on uplink:

- **UE-common resource for feedback:** Multiple UEs receiving the same downlink multicast transmission transmit HARQ feedback on the same uplink resource.
- **UE-specific resource for feedback:** Different UEs receiving the same downlink multicast transmission transmit HARQ feedback on different uplink resources.

[0030] For feedback using UE-common resources, an eNB allocates a common uplink resource for users with the same group-RNTI for multicast feedback. If a UE fails to receive downlink transmission then the UE transmits a negative acknowledgement (NACK) on the UE-common resource. If the UE successfully receives the downlink transmission then the UE does not transmit anything on the UE-common resource. Accordingly, the eNB can determine whether the downlink transmission is successfully received by the group of users through an energy measurement on the UE-common resource. More specifically, once enough energy is detected on the UE-common resource, the eNB can determine that at least one UE failed to receive the downlink transmission and will then retransmit the message.

[0031] For feedback using UE-specific resources, different UEs transmit feedback on orthogonal uplink resources and eNB needs to detect each UE-specific resource. The UE-common resource can significantly reduce the overhead for HARQ feedback as compared to the UE-specific resource option, but has the shortcoming that eNB is unable to distinguish the feedbacks among different UEs. This leads to a situation where the eNB will not retransmit a packet to a UE in a group when that UE failed to receive PDCCH or when a NACK from the UE is missed while all other UEs in the group successfully receive PDCCH and PDSCH. It is also possible there may be multiple UEs who failed to receive PDCCH or whose (superimposed) NACKs are missed by the eNB, and the eNB will not perform a retransmission to these UEs, if all other UEs in the group successfully receive PDCCH and PDSCH.

[0032] Uplink HARQ feedback on PUCCH perceived on the eNB side in current LTE systems is categorized into 3 cases: ACK, NACK, and DTX. The last case relates to when a PDCCH is missing at the UE and therefore the UE did not transmit any feedback. DTX is determined normally by energy detection, and thus current LTE eNBs use an energy threshold to distinguish between ACK/NACK and DTX. Such energy detection and/or monitoring is generally described in the following documents: Improved ACK/NACK DTX detection for LTE (EP 2811677 A2) and DTX detection when ACK/NACK is transmitted with scheduling request (US 8121082 B2).

[0033] The exemplary embodiments herein describe techniques for feedback for downlink multicast based on inter-user cooperation. Additional description of these techniques is presented after a system into which the exemplary embodiments may be used is described.

[0034] Turning to FIG. 1, this figure shows a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced. In FIG. 1, a user equipment (UE) 110 is in wireless communication with a wireless network 100. A UE is a wireless, typically mobile device that can access a wireless network. The UE 110 includes one or more processors 120, one or more memories 125, and one or more transceivers 130 interconnected through one or more buses 127. Each of the one or more transceivers 130 includes a receiver, Rx, 132 and a transmitter, Tx, 133. The one or more buses 127 may be address, data, or control buses, and may

include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers 130 are connected to one or more antennas 128. The one or more memories 125 include computer program code 123. The UE 110 includes a
5 feedback module 140, comprising one of or both parts 140-1 and/or 140-2, which may be implemented in a number of ways. The feedback module 140 may be implemented in hardware as feedback module 140-1, such as being implemented as part of the one or more processors 120. The feedback module 140-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In
10 another example, the feedback module 140 may be implemented as feedback module 140-2, which is implemented as computer program code 123 and is executed by the one or more processors 120. For instance, the one or more memories 125 and the computer program code 123 may be configured to, with the one or more processors 120, cause the user equipment 110 to perform one or more of the operations as described herein. The
15 UE 110 communicates with eNB 170 via a wireless link 111.

[0035] The eNB (evolved NodeB) 170 is a base station (e.g., for LTE, long term evolution) that provides access by wireless devices such as the UE 110 to the wireless network 100. The eNB 170 includes one or more processors 152, one or more memories 155, one or more network interfaces (N/W I/F(s)) 161, and one or more transceivers
20 160 interconnected through one or more buses 157. Each of the one or more transceivers 160 includes a receiver, Rx, 162 and a transmitter, Tx, 163. The one or more transceivers 160 are connected to one or more antennas 158. The one or more memories 155 include computer program code 153. The eNB 170 includes an allocation module 150, comprising one of or both parts 150-1 and/or 150-2, which may
25 be implemented in a number of ways. The allocation module 150 may be implemented in hardware as allocation module 150-1, such as being implemented as part of the one or more processors 152. The allocation module 150-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the allocation module 150 may be implemented as allocation module
30 150-2, which is implemented as computer program code 153 and is executed by the one or more processors 152. For instance, the one or more memories 155 and the computer program code 153 are configured to, with the one or more processors 152, cause the

eNB 170 to perform one or more of the operations as described herein. The one or more network interfaces 161 communicate over a network such as via the links 176 and 131. Two or more eNBs 170 communicate using, e.g., link 176. The link 176 may be wired or wireless or both and may implement, e.g., an X2 interface.

5 **[0036]** The one or more buses 157 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers 160 may be implemented as a remote radio head (RRH) 195, with the other elements of the eNB
10 170 being physically in a different location from the RRH, and the one or more buses 157 could be implemented in part as fiber optic cable to connect the other elements of the eNB 170 to the RRH 195.

[0037] It is noted that description herein indicates that “cells” perform functions, but it should be clear that the eNB that forms the cell will perform the functions. The cell
15 makes up part of an eNB. That is, there can be multiple cells per eNB. For instance, there could be three cells for a single eNB carrier frequency and associated bandwidth, each cell covering one-third of a 360 degree area so that the single eNB’s coverage area covers an approximate oval or circle. Furthermore, each cell can correspond to a single carrier and an eNB may use multiple carriers. So if there are three 120 degree cells per
20 carrier and two carriers, then the eNB has a total of 6 cells.

[0038] The wireless network 100 may include a network control element (NCE) 190 that may include MME (Mobility Management Entity)/SGW (Serving Gateway) functionality, and which provides connectivity with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). The eNB
25 170 is coupled via a link 131 to the NCE 190. The link 131 may be implemented as, e.g., an S1 interface. The NCE 190 includes one or more processors 175, one or more memories 171, and one or more network interfaces (N/W I/F(s)) 180, interconnected through one or more buses 185. The one or more memories 171 include computer program code 173. The one or more memories 171 and the computer program code 173
30 are configured to, with the one or more processors 175, cause the NCE 190 to perform one or more operations.

[0039] The wireless network 100 may implement network virtualization, which is the process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, a virtual network. Network virtualization involves platform virtualization, often combined with resource
5 virtualization. Network virtualization is categorized as either external, combining many networks, or parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors 152 or 175 and memories 155 and 171, and also such
10 virtualized entities create technical effects.

[0040] The computer readable memories 125, 155, and 171 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed
15 memory and removable memory. The computer readable memories 125, 155, and 171 may be means for performing storage functions. The processors 120, 152, and 175 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture,
20 as non-limiting examples. The processors 120, 152, and 175 may be means for performing functions, such as controlling the UE 110, eNB 170, and other functions as described herein.

[0041] In general, the various embodiments of the user equipment 110 can include, but are not limited to, vehicles (referred to herein as a vehicle UE), cellular telephones such
25 as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication
30 capabilities, Internet appliances permitting wireless Internet access and browsing, tablets with wireless communication capabilities, as well as portable units or terminals that incorporate combinations of such functions.

[0042] Having thus introduced one suitable but non-limiting technical context for the practice of the exemplary embodiments of this invention, the exemplary embodiments will now be described with greater specificity.

5 [0043] When a multicast transmission between an eNB and a group of UEs there must be a guarantee that every UE in the group can correctly receive the data multicasted from the eNB. As mentioned above, with the UE-common resource option for feedback an eNB is unable to distinguish between feedback from a particular UEs in a group, which may lead to the following situations:

- 10 • If one or more UEs in a group fail to receive PDCCH (e.g. due to poor channel quality between the UE and the eNB) and consequently do not transmit NACK while all other UEs in the group receive PDCCH and PDSCH successfully, then the eNB may not detect energy on the common feedback resource. In this case the eNB will regard it as a successful multicast transmission, and the eNB will not retransmit the packet to the
15 UEs that failed to receive the PDCCH.
- If an eNB fails to receive the NACK from a UE in the group due to poor channel condition between them while all other UEs in this group receive PDCCH and PDSCH successfully, the eNB will not detect the failure of
20 reception. In this case it is also possible that the NACKs from multiple users who incorrectly received PDSCH cannot be detected by the eNB because the channels between them and the base station are very weak such that the accumulated energy does not exceed the NACK detection threshold.

[0044] In the current release of 3GPP LTE, to handle the problem of missing PDCCH in TDD, a downlink assignment index (DAI) field in PDCCH indicates the number of
25 subframes containing PDSCH transmissions in a HARQ feedback window. Similar methods as DAI can be used to detect PDCCH missing in SC-PTM by indicating the accumulated number of transmissions thus enabling UE to recognize whether it has missed previous downlink assignments. A DAI-based method may partially account for the first situation above, but the drawback is that a UE cannot recognize missed
30 PDCCH until the next scheduling which causes additional latency. Further, the

DAI-based method cannot handle the second situation above, namely, when a NACK is not detected by the eNB.

5 [0045] Exemplary embodiments described herein provide techniques for feedback without additional latency based on inter-user cooperation when a PDCCH is missing at the UE side or when a NACK is missing at the eNB side. The exemplary embodiments leverage the fact that direct communications between UEs are readily supported in V2X, and that the favorable channel conditions are provided due to the proximity between UEs in the same group.

10 [0046] According to exemplary embodiments, a sidelink between a group of UEs receiving the same multicast transmission is used and two sequential resources on the sidelink (referred to herein as R1 and R2, respectively) are allocated to UEs in the same group. Since UEs always need to detect signals on PSCCH for V2V messages, the detection of R1 will not increase the complexity of UE reception, if R1 is located on PSCCH. All UEs in the group that have successfully received a downlink assignment
15 via PDCCH may transmit an “inter-user scheduling indicator” on R1. All of the UEs that did not receive PDCCH will detect the inter-user scheduling indication on R1, and in this way R1 is similar to a broadcast transmission from the UEs who successfully received the downlink assignment on PDCCH. It is noted that the UEs transmitting the inter-user scheduling indicator will not also try to receive over R1. Any UE in the group
20 that did not receive PDCCH (if such a UE exists) may determine the PDCCH is missing by checking if the energy level is above certain threshold (i.e. at least one other UE having received downlink assignment) via energy measurement or signal decoding on R1. It is noted that as long as there is at least one UE in the group who successfully decodes the downlink assignment, then the other users who did not decode assignment
25 can be indicated of that fact by detecting R1. Additionally, the more UEs that successfully decode the assignment, the more reliably the other UEs may detect R1 since there will be more energy over R1.

[0047] It is noted that the resource allocation of R1 can be performed in a number of different ways, for example, the allocation could be pre-configured, semi-persistently
30 configured, or dynamically configured. One non-limiting example is to define timing between PDCCH and R1, such that if PDCCH is received in a subframe n, then R1 will

be transmitted in subframe $n+1$. In some examples, the specific frequency resource location may be configured by the base station when the D2D group is set up. Different D2D groups may also be allocated with different frequency locations to avoid collision. After receiving PDCCH for multicast, the UE transmits a signal, which is referred to
5 herein as an inter-user scheduling indicator, on R1.

[0048] Similar to R1, a resource referred to R2 is needed on PSCCH of a sidelink that is used to determine if a NACK missing. R2 may, for example, be configured similarly as R1 above. UEs which have failed to receive PDSCH or PDCCH shall transmit a signal called “inter-user NACK indicator” on R2 before transmitting a NACK on the
10 UE-common resource. UEs that have successfully received PDSCH in the same group shall measure the energy on R2. If energy is detected a UE shall transmit NACK to eNB even if it has successfully received the PDSCH transmission. Thus, R2 is used to address the situation where the eNB fails to receive a NACK from a single UE, or from multiple UEs whose (superimposed) ACKs are not detected by the eNB, and
15 subsequently does not perform retransmission of the packet that would cause an unreliable multicast transmission.

[0049] The above two mechanisms involving R1 and R2 help address the problem of PDCCH missing at UE and NACK missing at eNB, respectively, through inter-user cooperation. In the proposed mechanisms, signals on R1 and R2 are transmitted after
20 receiving PDCCH and before transmitting NACK to eNB. Furthermore, the location of R1 is prior to the location of R2.

[0050] Referring now to FIG. 2, this figure shows a simplified example of V2X multicast scenario in accordance with exemplary embodiments. In V2X service, messages transmitted from a vehicle UE 203 need to be received by multiple UEs 204
25 in a neighboring area. In the example shown in FIG. 2, UE 203 transmits a V2X message to eNB 202 as shown by arrow 210. The base station 202 then transmits this message to multiple UEs 204 via multicast transmission as shown by arrow 212. In this example, the multiple UEs 204 are a group of users with the same group-RNTI as indicated by 206.

[0051] Referring also to FIG. 3, this figure shows a V2X multicast scenario with inter-user cooperation based feedback in accordance with exemplary embodiments. In
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this figure, a vehicle UE 303 transmits a message to eNB 302 as indicated by arrow 310. The eNB 302 then transmits this message to the group of UEs 304-1, 304-2, 304-3 via multicast as indicated by arrow 312 via PDCCH/PDSCH transmissions. The group of UEs 304-1, 304-2, 304-3 may communicate information via a sidelink 315, such as inter-scheduling and inter-NACK indicators for example. Each of the UEs 304-1, 304-2, 304-3 may also provide feedback via allocated resources common to the group of UEs as indicated by arrow 314. For clarity, FIG. 3 shows only one eNB and four UEs but this is not intended to be limiting, for instance, there could be more or less UEs, eNBs, etc.

- 10 [0052] According to embodiments, the inter-user scheduling indicator signal could be configured to either bear information or not bear information. When no specific information is beared in the signal on R1, UEs that did not receive PDCCH may determine whether a scheduling message was missed based on an energy measurement on R1. Thus, if a UE detects inter-user scheduling indicator on R1 but did not receive PDCCH in the corresponding prior subframe, it will regard it as a PDCCH reception failure and transmit a NACK to the eNB on the corresponding subframe afterwards.

- 20 [0053] When specific information is beared in the signal on R1, information related to the sequence number of the current PDSCH transmission can be carried on R1. This is helpful for the following scenario: a UE receives PDSCH successfully during initial transmission but fails to receive the PDCCH for retransmission caused by other UEs' PDSCH reception failure. If this UE simply detects energy on R1, it will regard it as an indication for failure of PDCCH reception and this may cause an unnecessary retransmission since this UE has already received the message successfully during the initial transmission. Therefore, specific information related to the sequence number of the current PDSCH can be beared in the signal on R1. In particular, the information may include HARQ process ID and a new data indicator (NDI) (e.g. as described by 3GPP TS 36.321), which can both be obtained after decoding PDCCH.

- 30 [0054] The UE that failed to receive PDCCH and detects energy on associated R1 can determine whether the current PDSCH is a retransmission based on the NDI after it decodes the signal in R1. For example, the current PDSCH is considered to be a retransmission if the NDI bit is not toggled when compared to the latest NDI value

corresponding to the HARQ process indicated in the current PDCCH. If it is a retransmission, the UE can further determine whether it has successfully received the PDSCH based on the HARQ process ID.

For example, the current PDSCH is considered to have been successfully received by a particular UE if the indicated HARQ process of the particular UE does not expect a retransmission, which encountered neither a PDSCH decoding failure nor a PDCCH missing after the latest correct PDSCH decoding. For this purpose, two flags should be maintained for each HARQ process. The first flag is used to record the latest NDI value corresponding to each HARQ process, which has already been implemented in the current LTE system. The second flag is used to determine whether a retransmission is expected for each particular HARQ process, which is set to be NO each time a PDSCH is received correctly over a HARQ process. The second flag is set to YES each time a PDSCH is received incorrectly over a HARQ process or a PDCCH is missing for a HARQ process, which can be determined via inter-user scheduling indicator as described by exemplary embodiments. If the UE has successfully received the current PDSCH then a NACK will not be issued.

[0055] Referring now to FIG. 4, this figure shows an example signaling diagram for inter-user cooperation based feedback mechanism in accordance with exemplary embodiment. An eNB (e.g. eNB 302 from FIG. 3) transmits PDCCH signals 402, 404, 406 to a group of UEs, which includes UE1 (e.g. 304-1 from FIG. 3), UE2 (e.g. 304-2), and UE3 (e.g. 304-3). The PDCCH includes a downlink assignment for a multicast transmission to the group of UEs. Subsequently the eNB transmits data via the PDSCH to the group of UE1, UE2, and UE3 using a multicast transmission as indicated by signals 408, 410, and 412, respectively. In this example, UE1 successfully receives PDCCH signal 402 and PDSCH signal 408; UE 2 fails to receive PDCCH signal 404, and UE3 fails to receive PDSCH signal 412. R1 416 are resources allocated for transmitting an inter-scheduling indicator 422, and R2 418 are resources for transmitting an inter-user NACK indicator 424. Indicators 422, 424 are transmitted among the group of UE1, UE2, and UE3 via a sidelink (such as sidelink 315 from FIG. 3). FIG. 4 also shows UE-common resources 420 allocated for transmitting NACKs from the group of UEs to the eNB. The determination on whether each of the UE1, UE2,

and UE3 transmits an inter-scheduling indicator 422, inter-user NACK indicator 424, or a NACK 426 is described in further detail with reference to FIGS. 5-7.

[0056] Referring also to FIG. 5, this figure is logic flow diagrams showing the behavior of a UE in response to PDCCH reception when the inter-user scheduling indicator does not include specific information. In FIG. 5 it is assumed that the UE is in a group of UEs for multicast transmission. At 502 the UE is transmitted a signal via PDCCH from a base station. If the UE successfully receives the signal at 504, then the UE transmits an inter-user scheduling indicator on R1 as shown at 508. If a PDCCH signal has not been received at 504, then the UE monitors the sidelink at R1 for inter-user scheduling indicators from other UEs in the group as shown at 506. For example, the UE may monitor R1 by measuring if the energy received at R1 exceeds some predetermined threshold. At 510, if no inter-user scheduling indicator is detected based on the monitoring, then the UE does not transmit feedback on the UE-common resource as shown at 512. If an inter-user scheduling indicator is detected then a NACK is transmitted at 514 on the UE-common resources to indicate that the UE did not receive the PDCCH at 502. It is noted that before transmitting the NACK to the eNB, an inter-user NACK indicator is also transmitted on R2 by this UE.

[0057] Referring now to FIG. 6, this figure is a logic flow diagram showing the behavior of a UE in response to PDCCH reception when the inter-user scheduling indicator includes specific information. Similar to FIG. 5, it is assumed that the UE is in a group of UEs for multicast transmission from a base station. At 602 the UE is transmitted a PDCCH signal from a base station. If the signal is successfully received at 604, then the UE transmits an inter-user scheduling indicator on R1 as shown at 606; otherwise the UE monitors and attempts to decode a signal received on R1 from other UEs in the group as shown at 608. If the decoding is unsuccessful at 610, then the UE does not transmit feedback on the UE-common resources as shown at 612. If the decoding is successful at 610, then flow continues to 614 where the UE determines whether the signal is for a retransmission. If it is not related to a retransmission, then the UE transmits a NACK on the UE-common resources. If the signal is for a retransmission, the UE determines whether the signal has already been successfully received at 618, and if not, then the UE transmits a NACK as shown at 620. If, at 618, the signal has been successfully received by the UE then the does not transmit feedback

as indicated by 622. It is noted that an inter-user NACK indicator is transmitted before transmitting the NACK to the eNB.

[0058] FIG. 7 is a logic flow diagram that presents UE behavior in response to PDSCH reception in accordance with exemplary embodiments. Again, it assumed that the UE is in a group of UEs for multicast transmission from a base station. At 702, the user equipment is transmitted a PDSCH signal from the base station. If the UE determines that the signal was successfully received at 704, then the UE measures energy on R2 in order to detect inter-user NACK indicator signals from other user equipments in the group as shown at 710. If, at 712, the UE determines an inter-user NACK indicator signal is detected, then the UE transmits a NACK to the base station as indicated by 716. If, at 712, the UE determines an inter-user NACK indicator signal is not detected, then the UE does not transmit feedback on the UE-common resources as shown at 714. If the UE failed to receive the PDSCH signal at 704, then the UE transmits an inter-user NACK indicator as indicated by 706, and transmits a NACK to the base station as indicated by 708.

[0059] Referring again to FIG. 4, UE1 successfully received PDCCH signal 402 and therefore transmits the inter-user scheduling indicator 422 on R1 416 based on the UE behavior from FIGS. 5 and 6. UE1 does not transmit an inter-user NACK indicator since UE1 successfully received the PDSCH signal 408, but transmits a NACK 426 since UE1 would detect the inter-user NACK indicator 424 from UE2 and UE3 in FIG. 4.

[0060] UE 2 fails to receive PDCCH signal 404, and UE3 fails to receive PDSCH signal 412. R1 416 are resources allocated for transmitting an inter-scheduling indicator 422, and R2 418 are resources for transmitting an inter-user NACK indicator 424

[0061] FIGS. 8 and 9 are a logic flow diagrams for feedback for downlink multicast based on inter-user cooperation, and illustrate the operation of exemplary methods, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the feedback module 140-1 and/or 140-2 may include multiples ones of the blocks in FIGS. 8 and 9, where each included block is an

interconnected means for performing the function in the block. The blocks in FIGS. 8 and 9 are assumed to be performed by the UE 110, e.g., under control of the feedback module 140-1 and/or 140-2 at least in part.

[0062] Referring now to FIG. 8, according to an exemplary embodiment a method is provided including receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment as indicated by block 802; and transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment as indicated by block 804.

[0063] The method may further comprise, in response to determining that the multicast transmission was successfully received by the first user equipment, monitoring, by the first user equipment, a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission. The method may further comprise in response to detecting the second indication on the second resource, transmitting a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback. The monitoring may include performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold. The method may further include, in response to determining that the multicast transmission was not successfully received by the first user equipment, transmitting a second indication on a second resource to at least one user equipment in the group indicating that the multicast transmission was not successfully received. The method may further include in response to determining that the multicast transmission was not successfully received by the first user equipment, transmitting a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback. The group of user equipments may be configured to communicate via device-to-device communications. The control information may be received via a physical downlink control channel. The multicast transmission may be received via a physical downlink shared channel. The first resource and the second resource may be

allocated on a physical sidelink control channel. The user equipments in the group may share a group radio network temporary identifier.

[0064] According to another exemplary embodiment, an apparatus is provided comprising at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following: receive, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and transmit, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

[0065] In response to determination that the multicast transmission was successfully received by the first user equipment, the at least one memory and the computer program code may be further configured to, with the at least one processor, cause the apparatus to perform at least the following: monitor, by the first user equipment, a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission. In response to detection of the second indication on the second resource, the at least one memory and the computer program code may be further configured to, with the at least one processor, cause the apparatus to perform at least the following: transmit a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback. The monitoring may include performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold. In response to determination that the multicast transmission was not successfully received by the first user equipment, the at least one memory and the computer program code are may be configured to, with the at least one processor, cause the apparatus to perform at least the following: transmit a second indication on a second resource to at least one user equipment in the group indicating that the multicast transmission was not successfully received. The at least one memory and the computer program code may be further configured to, with the at least one processor, cause the apparatus to perform at

least the following: in response to determining that the multicast transmission was not successfully received by the first user equipment, transmit a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback. The group of user equipments may be configured to communicate
5 via device-to-device communications. The control information may be received via a physical downlink control channel. The multicast transmission may be received via a physical downlink shared channel. The first resource and the second resource may be allocated on a physical sidelink control channel. The user equipments in the group may share a group radio network temporary identifier. A user equipment may comprise the
10 apparatus.

[0066] According to another exemplary embodiment, an apparatus is provided including: means for receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user
15 equipment; and means for transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

[0067] Referring now to FIG. 9, a method may including receiving, at a second user equipment from at least one first user equipment, a first indication that control
20 information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group as indicated by block 902;
25 determining that the control information was not successfully received at the second user equipment based on the first indication as indicated by block 904; and transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission as indicated by block 906.

[0068] The receiving may further comprise decoding information received on the first
30 resource relating to the multicast transmission; determining from the decoded information that the multicast transmission is a retransmission of a prior multicast

transmission; and not transmitting the NACK of the multicast transmission to the base station if the prior multicast transmission was successfully received by the second user equipment. The decoded information may include at least one of a new data indicator; and a hybrid automatic repeat request process identification. The method may include, in response to successfully receiving the multicast transmission, monitoring by the second user equipment a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission. The monitoring may include performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold.

[0069] According to another exemplary embodiment, an apparatus is provided, comprising: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following: receive, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and determine that the control information was not successfully received at the second user equipment based on the first indication; and transmit, to the base station, a negative acknowledgement (NACK) of the multicast transmission.

[0070] The receiving may further include decoding information received on the first resource relating to the multicast transmission; determining from the decoded information that the multicast transmission is a retransmission of a prior multicast transmission; and not transmitting the NACK of the multicast transmission to the base station if the prior multicast transmission was successfully received by the second user equipment. The decoded information may be at least one of a new data indicator, and a hybrid automatic repeat request process identification. The at least one memory and the computer program code may be further configured to, with the at least one processor, cause the apparatus to perform at least the following: in response to successfully

reception of the multicast transmission, monitor by the second user equipment a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission. The monitoring may include performing an energy measurement on the second resource to
5 detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold.

[0071] According to yet another exemplary embodiment, an apparatus is provided including means for receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at
10 least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and means for determining that the control information was not
15 successfully received at the second user equipment based on the first indication; and means for transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission.

[0072] FIG. 10 is a logic flow diagrams for feedback for downlink multicast based on inter-user cooperation, and illustrate the operation of exemplary methods, a result of
20 execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the allocation module 150-1 and/or 150-2 may include multiples ones of the blocks in FIG. 10, where each included block is an interconnected means for performing the function
25 in the block. The blocks in FIG. 10 are assumed to be performed by the base station 170, e.g., under control of the allocation module 150-1 and/or 150-2 at least in part.

[0073] Referring now to FIG. 10, a method may including allocating, by a base station, at least a first resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein
30 the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to the multicast transmission

was successfully received, and wherein the second resource is used to for communicating a second indication between the group of user equipments of whether the multicast transmission was successfully received as indicated by block 1002; receiving, at the base station, the feedback on a third resource shared by the group of user equipments as indicated by block 1004; and determining whether to retransmit the multi-cast transmission to the group of user equipments based on the feedback as indicated by block 1006.

[0074] According to another exemplary embodiment, an apparatus includes: at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following: allocate, by a base station, at least a first resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to the multicast transmission was successfully received, and wherein the second resource is used to for communicating a second indication between the group of user equipments of whether the multicast transmission was successfully received; receive, at the base station, the feedback on a third resource shared by the group of user equipments; and determine whether to retransmit the multi-cast transmission to the group of user equipments based on the feedback.

[0075] According to another embodiment, a computer program may be provided comprising program code for executing any one of the methods above. The computer program may be a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer.

[0076] According to another embodiment, a communication system may include at least two of the apparatuses described above.

[0077] Without in any way limiting the scope, interpretation, or application of the claims appearing below, a technical effect of one or more of the example embodiments disclosed herein is that it ensures all UEs in a group can detect PDCCH is missing during the current transmission and can therefore immediately transmit a NACK to an

eNB to trigger retransmission, thus improving reliability under the strict requirement on latency by handling the situation where retransmission cannot be promptly performed due to the PDCCH missing for at least one UE. Another technical effect of one or more of the example embodiments disclosed herein is improves the reliability of NACK
5 detection at eNB by handling the situation where retransmission cannot be performed due to NACK missing of at least one UE. Another technical effect of one or more of the example embodiments disclosed herein is keeping the benefit of UE-common resource feedback, which significantly reduces overhead of HARQ feedback compared with UE-specific resource feedback. The resources R1 and R2 on PSCCH introduced will
10 not significantly increase the reception complexity of UEs since the UEs always need to detect messages on PSCCH for V2V reception, which allows seamless integration with V2X applications.

[0078] Embodiments herein may be implemented in software (executed by one or more processors), hardware (e.g., an application specific integrated circuit), or a combination
15 of software and hardware. In an example embodiment, the software (e.g., application logic, an instruction set) is maintained on any one of various conventional computer-readable media. In the context of this document, a “computer-readable medium” may be any media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution
20 system, apparatus, or device, such as a computer, with one example of a computer described and depicted, e.g., in FIG. 1. A computer-readable medium may comprise a computer-readable storage medium (e.g., memories 125, 155, 171 or other device) that may be any media or means that can contain, store, and/or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such
25 as a computer. A computer-readable storage medium does not comprise propagating signals.

[0079] If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined.

30 [0080] Although various aspects of the invention are set out in the independent claims, other aspects of the invention comprise other combinations of features from the

described embodiments and/or the dependent claims with the features of the independent claims, and not solely the combinations explicitly set out in the claims.

[0081] It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention as defined in the appended claims.

[0082] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

	eNB (or eNodeB)	evolved Node B (e.g., an LTE base station)
10	D2D	Device to Device
	DAI	Downlink Assignment Index
	I/F	interface
	LTE	long term evolution
	MBSFN	MBMS Single-Frequency Network
15	MCS	Modulation and Coding Scheme
	MME	mobility management entity
	NCE	network control element
	NDI	New-Data Indicator
	N/W	network
20	PSCCH	Physical Sidelink Control Channel
	PSSCH	Physical Sidelink Shared Channel
	RNTI	Radio Network Temporary Identifier
	RRH	remote radio head
	Rx	receiver
25	SA	Scheduling Assignment
	SCPTM	Single Cell Point to Multi-point

	SGW	serving gateway
	SL	sidelink
	Tx	transmitter
	UE	user equipment (e.g., a wireless, typically mobile device)
5	V2I/N	Vehicle to Infrastructure/Network
	V2P	Vehicle to Pedstrian
	V2V	Vehicle to Vehicle
	V2X	Vehicle to Anything

WHAT IS CLAIMED IS:

1. A method comprising:

receiving, at a first user equipment, control information from a base station of a
5 wireless network for a multicast transmission corresponding to a group of user
equipments comprising the first user equipment and at least one second user equipment;
and

transmitting, to the at least one second user equipment on a first resource
associated with the group, a first indication that the control information was
10 successfully received by the first user equipment.

2. The method of claim 1, further comprising:

in response to determining that the multicast transmission was successfully
received by the first user equipment: monitoring, by the first user equipment, a second
15 resource associated with the group for a second indication indicating whether at least
one user equipment in the group failed to receive the multicast transmission.

3. The method of claim 2, further comprising:

in response to detecting the second indication on the second resource,
20 transmitting a negative acknowledgement (NACK) of the multicast transmission to the
base station on a resource shared by the group for feedback.

4. The method of claim 2, wherein the monitoring comprises:

performing an energy measurement on the second resource to detect the second
25 indication, wherein the second indication is detected if the energy exceeds a
predetermined threshold.

5. The method of claim 1, further comprising:

in response to determining that the multicast transmission was not successfully received by the first user equipment, transmitting a second indication on a second resource to at least one user equipment in the group indicating that the multicast transmission was not successfully received.

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6. The method of claim 5, further comprising in response to determining that the multicast transmission was not successfully received by the first user equipment, transmitting a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback.

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7. The method of any one of the preceding claims, wherein the group of user equipments are configured to communicate via device-to-device communications.

8. The method of any one of the preceding claims, wherein at least one of:

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the control information is received via a physical downlink control channel;

the multicast transmission is received via a physical downlink shared channel;

and

the first resource and the second resource are allocated on a physical sidelink control channel.

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9. The method of any one of the preceding claims, wherein the user equipments in the group share a group radio network temporary identifier.

10. An apparatus, comprising:

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at least one processor; and

at least one memory including computer program code,

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user equipment; and

5 transmit, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

11. The apparatus of claim 10, wherein, in response to determining that the multicast
10 transmission was successfully received by the first user equipment, the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to perform at least the following:

 monitor, by the first user equipment, a second resource associated with the group for a second indication indicating whether at least one user equipment in the
15 group failed to receive the multicast transmission.

12. The apparatus of claim 11, wherein in response to detection of the second indication on the second resource, the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to perform at
20 least the following:

 transmit a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback.

13. The apparatus of claim 11, wherein the monitoring comprises:

25 performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold.

14. The apparatus of claim 10, wherein in response to determining that the multicast

transmission was not successfully received by the first user equipment, the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to perform at least the following:

- 5 transmit a second indication on a second resource to at least one user equipment in the group indicating that the multicast transmission was not successfully received.

15. The apparatus of claim 14, the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to perform at least the following:

- 10 in response to determining that the multicast transmission was not successfully received by the first user equipment, transmit a negative acknowledgement (NACK) of the multicast transmission to the base station on a resource shared by the group for feedback.

- 15 16. The apparatus of any one of claims 10 to 15, wherein the group of user equipments are configured to communicate via device-to-device communications.

17. The apparatus of any one of the claims 10 to 16, wherein at least one of:

- 20 the control information is received via a physical downlink control channel;
the multicast transmission is received via a physical downlink shared channel;
and
the first resource and the second resource are allocated on a physical sidelink control channel.

- 25 18. The apparatus of any one of the claims 10 to 17, wherein the user equipments in the group share a group radio network temporary identifier.

19. An apparatus, comprising:

means for receiving, at a first user equipment, control information from a base station of a wireless network for a multicast transmission corresponding to a group of user equipments comprising the first user equipment and at least one second user
5 equipment; and

means for transmitting, to the at least one second user equipment on a first resource associated with the group, a first indication that the control information was successfully received by the first user equipment.

10 20. A method comprising:

receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments
15 comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and

determining that the control information was not successfully received at the second user equipment based on the first indication; and

20 transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission.

21. The method of claim 20, wherein the receiving further comprises:

25 decoding information received on the first resource relating to the multicast transmission;

determining from the decoded information that the multicast transmission is a retransmission of a prior multicast transmission; and

30 not transmitting the NACK of the multicast transmission to the base station if the prior multicast transmission was successfully received by the second user equipment.

22. The method of claim 21, wherein the decoded information comprises at least one of:

a new data indicator; and

a hybrid automatic repeat request process identification.

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23. The method of claim 20, wherein the method further comprises:

in response to successfully receiving the multicast transmission, monitoring by the second user equipment a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission.

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24. The method of claim 23, wherein the monitoring comprises:

performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold.

15

25. An apparatus, comprising:

at least one processor; and

at least one memory including computer program code,

20 the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

receive, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and

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determine that the control information was not successfully received at the second user equipment based on the first indication; and

transmit, to the base station, a negative acknowledgement (NACK) of the multicast transmission.

5

26. The apparatus of claim 25, wherein the receiving further comprises:

decoding information received on the first resource relating to the multicast transmission;

10 determining from the decoded information that the multicast transmission is a retransmission of a prior multicast transmission; and

not transmitting the NACK of the multicast transmission to the base station if the prior multicast transmission was successfully received by the second user equipment.

15 27. The apparatus of claim 26, wherein the decoded information comprises at least one of:

a new data indicator; and

a hybrid automatic repeat request process identification.

20 28. The apparatus of claim 25, wherein the at least one memory and the computer program code are further configured to, with the at least one processor, cause the apparatus to perform at least the following:

25 in response to successful reception of the multicast transmission, monitor by the second user equipment a second resource associated with the group for a second indication indicating whether at least one user equipment in the group failed to receive the multicast transmission.

29. The apparatus of claim 28, wherein the monitoring comprises:

performing an energy measurement on the second resource to detect the second indication, wherein the second indication is detected if the energy exceeds a predetermined threshold.

5 30. An apparatus, comprising:

means for receiving, at a second user equipment from at least one first user equipment, a first indication that control information was successfully received at the at least one first user equipment from a base station of a wireless network, wherein the control information corresponds to a multicast transmission for a group of user equipments comprising at least the second user equipment and the at least one first user equipment, and wherein the first indication is received on a first resource associated with the group; and

means for determining that the control information was not successfully received at the second user equipment based on the first indication; and

15 means for transmitting, to the base station, a negative acknowledgement (NACK) of the multicast transmission.

31. An apparatus, comprising:

at least one processor; and

20 at least one memory including computer program code,

the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:

allocate, by a base station, at least a first resource and a second resource to a group user equipments for cooperatively determining feedback corresponding to a multicast transmission, wherein the first resource is used for communicating a first indication between the group of user equipments of whether control information corresponding to the multicast transmission was successfully received, and wherein the second resource is used to for communicating a second indication between the group of user equipments of whether the multicast transmission was successfully received;

30 receive, at the base station, the feedback on a third resource shared by the group

of user equipments; and

determine whether to retransmit the multi-cast transmission to the group of user equipments based on the feedback.

- 5 32. A user equipment comprising an apparatus according to any one of claims 10 to 18 or 26 to 29.

33. A communication system comprising an apparatus in accordance with claim 32 and an apparatus in accordance with any one of the claims 10 to 19 or 25 to 29.

10

34. A computer program comprising program code for executing the method according to any of claims 1 to 9 or 20 to 24.

- 15 35. The computer program according to claim 34, wherein the computer program is a computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer.

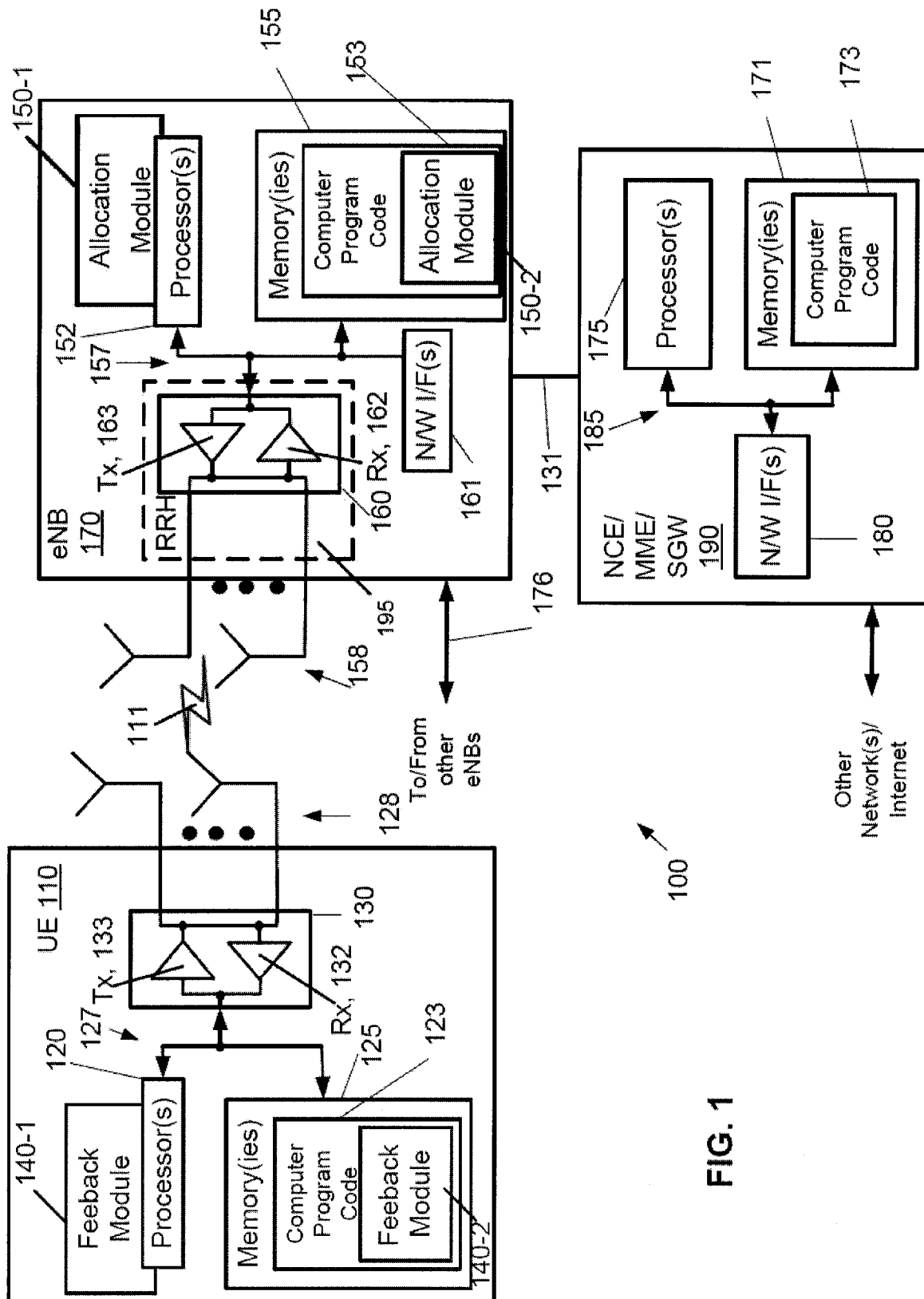


FIG. 1

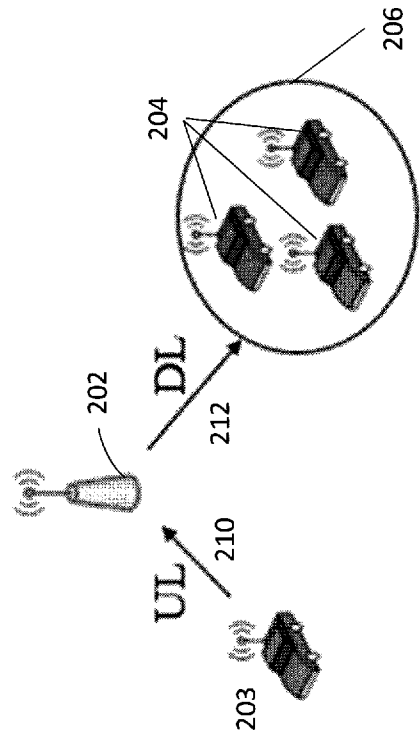


Fig. 2

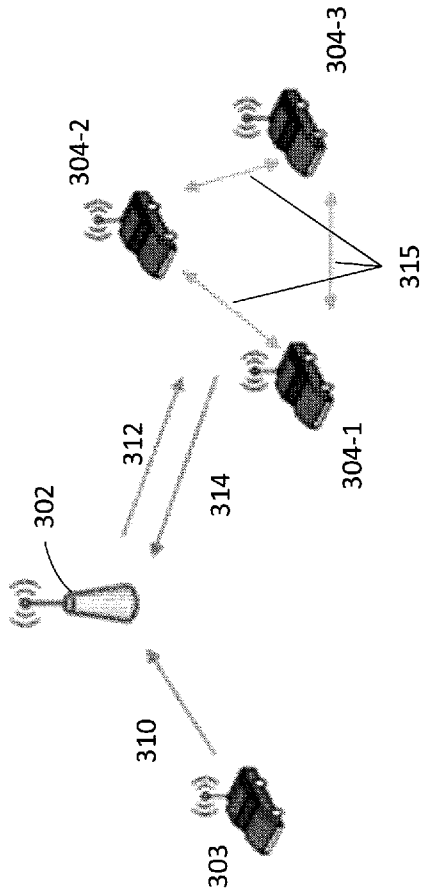


Fig. 3

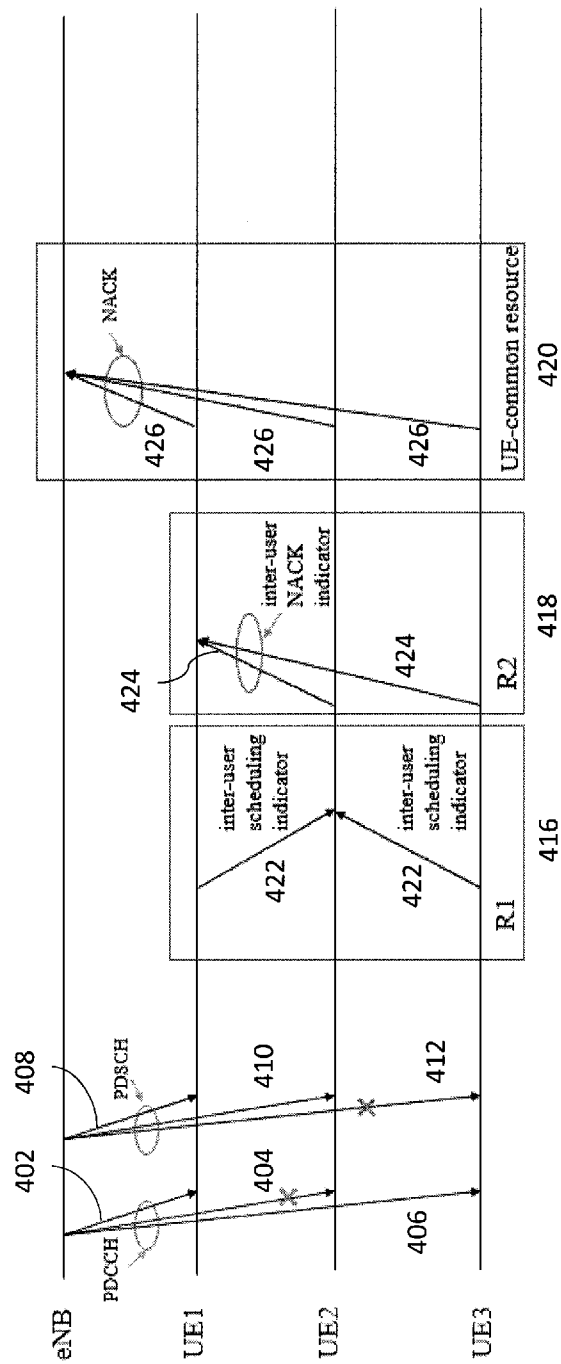


Fig. 4

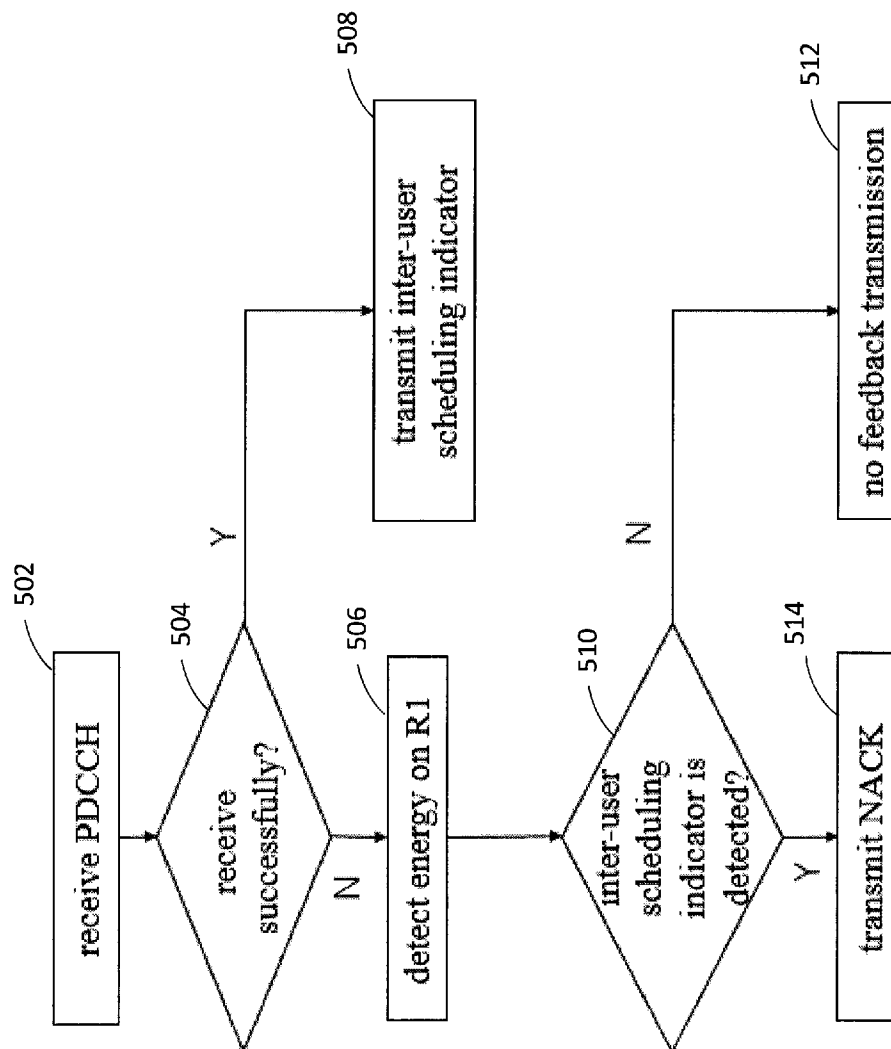


Fig. 5

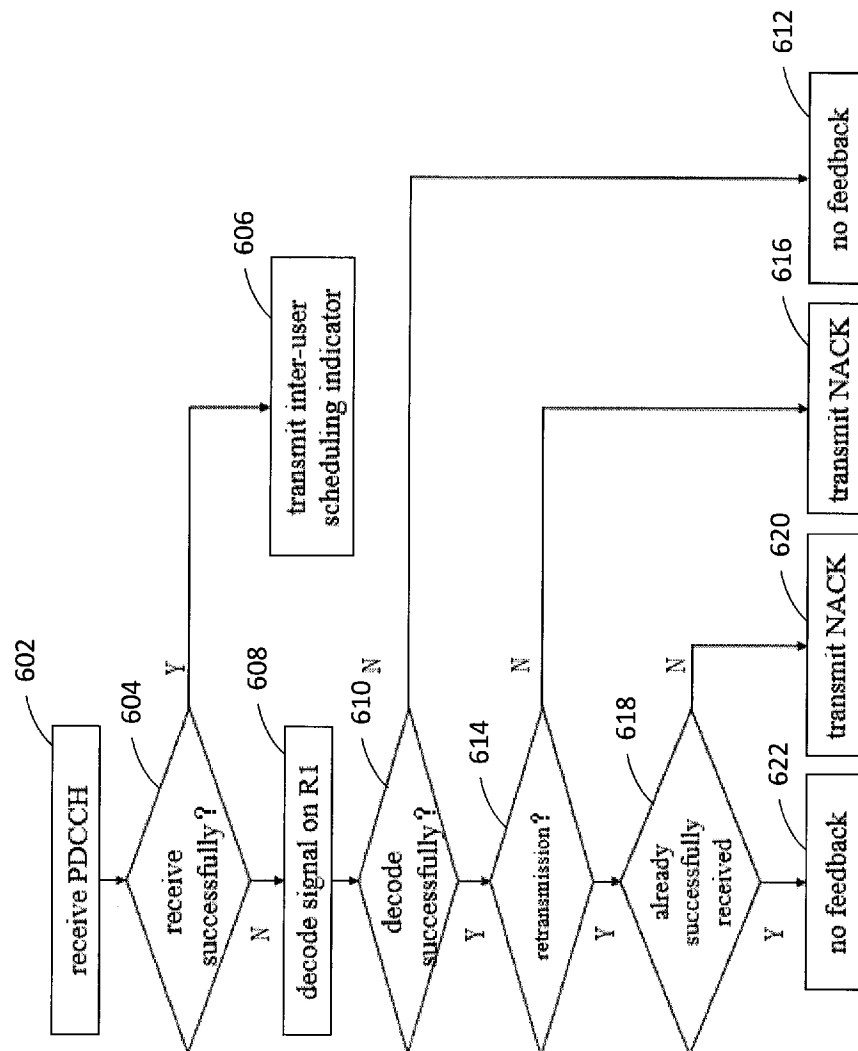


Fig. 6

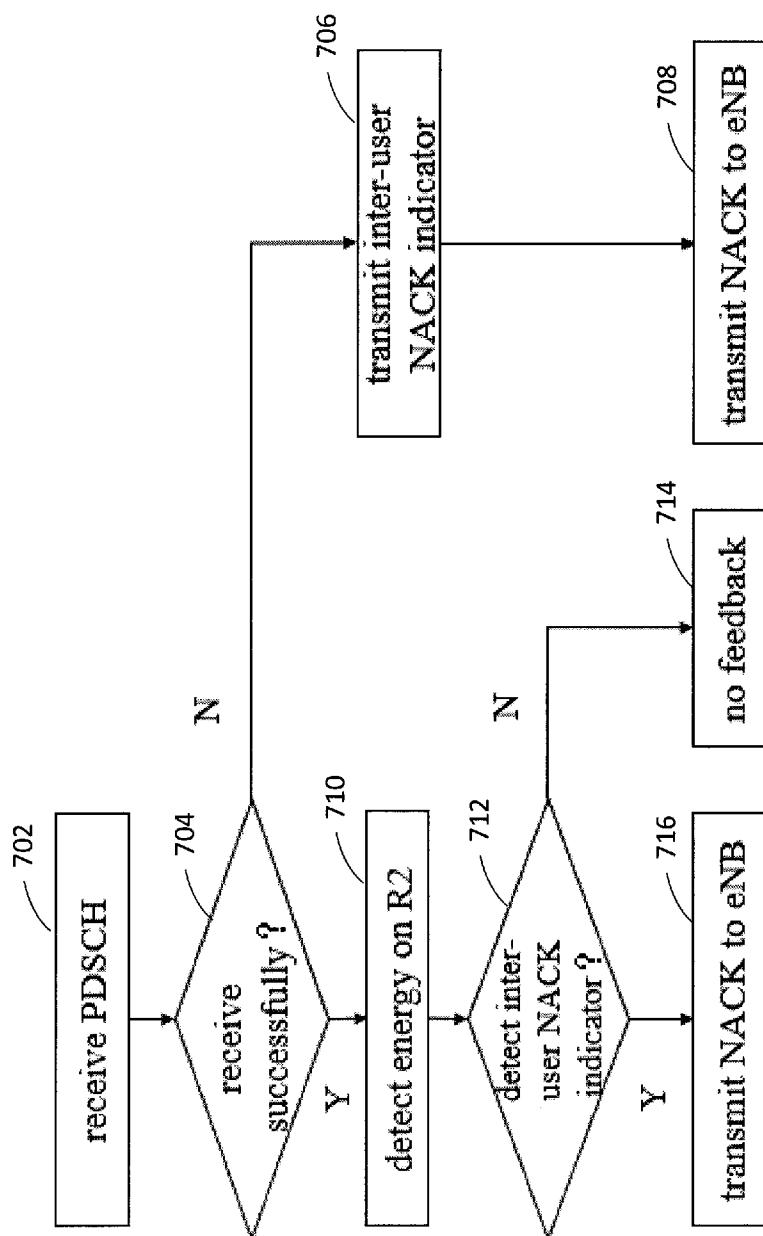


Fig. 7

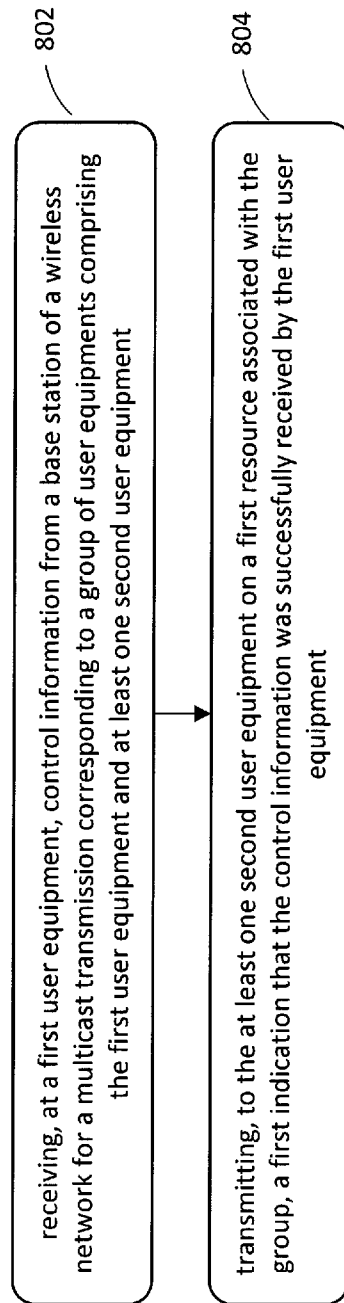


Fig. 8

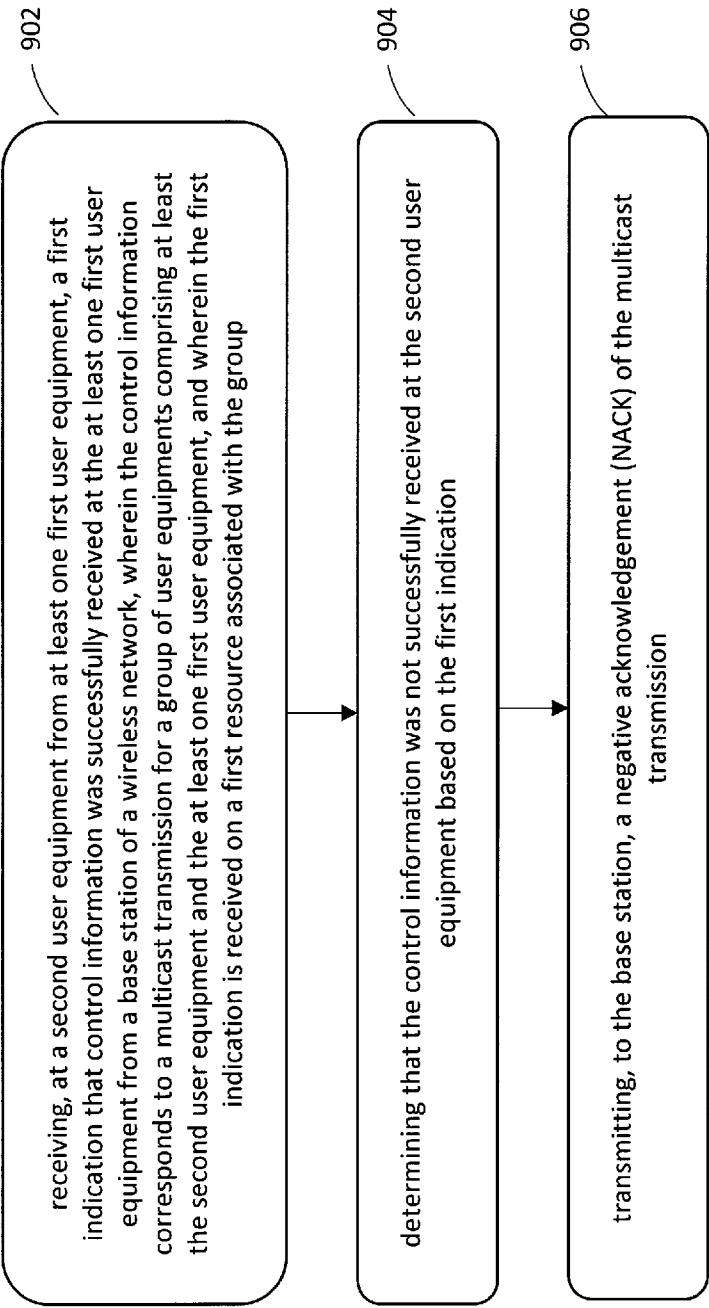


Fig. 9

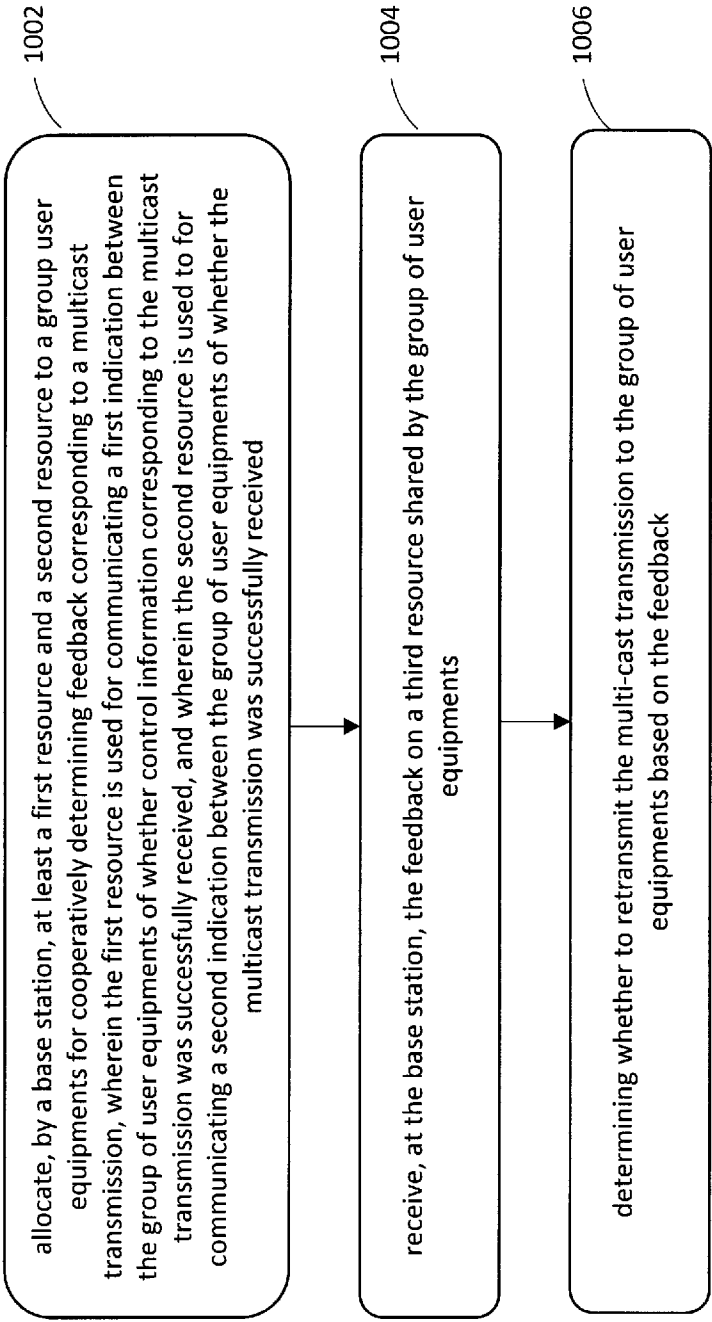


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/072432

A. CLASSIFICATION OF SUBJECT MATTER H04W 72/04(2009.01)i According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) H04W; H04L; H04Q 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) CNPAT,WPI,EPODOC,3GPP: BS or (base 1w station) or eNB or eNODEB or AP or (access 1w point), UE or user or client or terminal or MS or (mobile 1w station), send or sent or transmit or transmission or transfer or deliver or distribute, receive or receiving or reception or incept or accept or receipt, control or assign or allocation or PDCCH or retransmission or retransmit or feedback, D2D or (device 1w to 1w device) or V2V or V2X or (vehicle 1w to 1w vehicle) or (vehicle 1w to 1w anything) or sidelink, indicator or indication or notification or signal or instruction, broadcast or multicast				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	CN 103517276 A (HUAWEI TECHNOLOGIES CO., LTD.) 15 January 2014 (2014-01-15) the whole document	1-35		
A	CN 103002578 A (CHINA MOBILE COMMUNICATION CORPORATION) 27 March 2013 (2013-03-27) the whole document	1-35		
A	US 2012129540 A1 (NOKIA SIEMENS NETWORKS OY ET AL.) 24 May 2012 (2012-05-24) the whole document	1-35		
A	3GPP WORKING GROUP. "3GPP TR 36.843 V12.0.1" <i>3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Study on LTE Device to Device Proximity Services; Radio Aspects (Release 12).</i> , 31 March 2014 (2014-03-31), the whole document	1-35		
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
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Date of the actual completion of the international search 29 September 2017		Date of mailing of the international search report 19 October 2017		
Name and mailing address of the ISA/CN STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China Facsimile No. (86-10)62019451		Authorized officer NING,Bo Telephone No. (86-10)62413288		

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/072432

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	103517276	A	15 January 2014	CN	107071905	A	18 August 2017
				WO	2014000514	A1	03 January 2014
CN	103002578	A	27 March 2013	WO	2013034107	A1	14 March 2013
US	2012129540	A1	24 May 2012	EP	2641440	A1	25 September 2013
				WO	2012066433	A1	24 May 2012