



(51) International Patent Classification:
H04L 1/16 (2006.01)

(21) International Application Number:
PCT/CN2019/096282

(22) International Filing Date:
17 July 2019 (17.07.2019)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicants (for CN only): **NOKIA SHANGHAI BELL CO., LTD.** [CN/CN]; No.388, Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN). **NOKIA SOLUTIONS AND NETWORKS OY** [FI/FI]; Karakaari 7, Espoo, 02610 (FI).

(71) Applicant (for all designated States except CN): **NOKIA TECHNOLOGIES OY** [FI/FI]; Karakaari 7, Espoo, 02610 (FI).

(72) Inventor: **GUO, Haiyou**; No.388, Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN).

(74) Agent: **KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Centre, No.1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,

CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))

(54) Title: INTEGRATED SIGNALING OF HARQ ACKNOWLEDGEMENTS

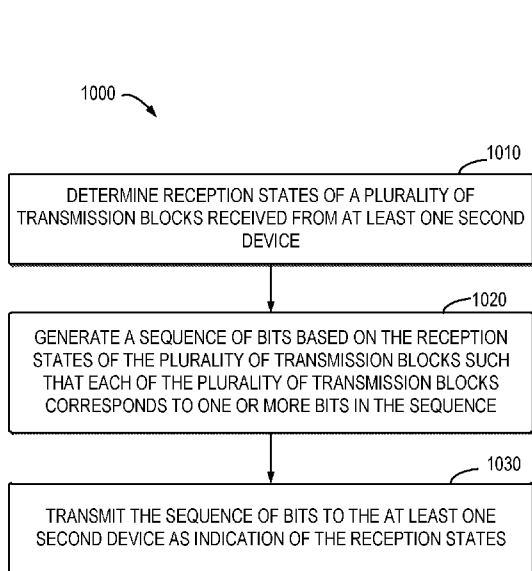


Fig. 10

(57) Abstract: Embodiments of the present disclosure relate to integrated signaling of Hybrid Automatic Repeat reQuest acknowledgements. A first device determines reception states of a plurality of transmission blocks received from at least one second device. The first device generates a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence. The first device transmits the sequence of bits to the at least one second device as indication of the reception states.



INTEGRATED SIGNALING OF HARQ ACKNOWLEDGEMENTS

FIELD

5 [0001] Embodiments of the present disclosure generally relate to the field of telecommunication and in particular, to methods, devices, apparatuses and computer readable storage media for integrated signaling of Hybrid Automatic Repeat reQuest (HARQ) acknowledgements.

10 BACKGROUND

[0002] The signaling of HARQ acknowledgement is an indispensable component of retransmission protocol. Most of wireless systems including 3GPP Long Term Evolution (LTE) and New Radio (NR) adopt HARQ with soft combining, relying on a combination of error-correcting coding and retransmission of erroneous data units. The HARQ provides
15 robustness against transmission errors and maintains multiple parallel stop-and-wait processes. Upon receipt of a transport block, the receiving device tries to decode the transport block and informs the transmitting device about the outcome of the decoding operation through a single acknowledgment bit indicating whether the decoding was successful or if a retransmission of the transport block is required.

20 [0003] In Media Access Control (MAC) of LTE and NR, a large transport block is segmented into multiple code blocks prior to coding. In addition to a Cyclic Redundancy Check (CRC) for the overall transport-block, each code block is configured with its own 24-bit CRC. Since each code block has its own CRC, errors can be detected on individual code blocks as well as on the overall transport block, a positive acknowledgment (ACK) in
25 the case of a successful decoding and a negative acknowledgment (NACK) in the case of unsuccessful decoding. A receiving device feeds back a single bit indicating positive or negative acknowledgement for each transport block, code block or group of code blocks, as part of control information. In case of an erroneously received data unit, a retransmission is requested from the corresponding transmitting device.

30

SUMMARY

[0004] In general, example embodiments of the present disclosure provide a solution for

integrated signaling of HARQ acknowledgements.

[0005] In a first aspect, there is provided a first device. The first device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the first device to determine reception states of a plurality of transmission blocks received from at least one second device; generate a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and transmit the sequence of bits to the at least one second device as indication of the reception states .

[0006] In a second aspect, there is provided a second device. The second device comprises at least one processor; and at least one memory including computer program codes; the at least one memory and the computer program codes are configured to, with the at least one processor, cause the second device to transmit a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device; receive at least one portion of a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and determine a reception state of the transmission block based on the at least one portion of the sequence of bits.

[0007] In a third aspect, there is provided a method. The method comprises determining reception states of a plurality of transmission blocks received from at least one second device; generating a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and transmitting the sequence of bits to the at least one second device as indication of the reception states.

[0008] In a fourth aspect, there is provided a method. The method comprises transmitting a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device; receiving a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and determining a reception state of the transmission block based on the sequence of bits.

[0009] In a fifth aspect, there is provided an apparatus comprising means for determining reception states of a plurality of transmission blocks received from at least one second

device; means for generating a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and means for transmitting the sequence of bits to the at least one second device as indication of the reception states.

5 [0010] In a sixth aspect, there is provided an apparatus comprising means for transmitting a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device; means for receiving a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and means for determining a reception state of the transmission block based on
10 the sequence of bits.

[0011] In a seventh aspect, there is provided a non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method according to the above third aspect.

[0012] In an eighth aspect, there is provided a non-transitory computer readable medium
15 comprising program instructions for causing an apparatus to perform at least the method according to the above fourth aspect.

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

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Some example embodiments will now be described with reference to the accompanying drawings, where:

25 [0015] Fig. 1 illustrates an example communication network in which embodiments of the present disclosure may be implemented;

[0016] Fig. 2 illustrates a diagram illustrating separated signaling of HARQ acknowledgements;

[0017] Fig. 3 illustrates a flowchart illustrating an example process for integrated
30 signaling of HARQ acknowledgements according to some embodiments of the present disclosure;

[0018] Fig. 4 illustrates a diagram illustrating integrated signaling of HARQ acknowledgements according to some embodiments of the present disclosure;

[0019] Fig. 5 illustrates a diagram illustrating an example process of HARQ-related information according to some embodiments of the present disclosure;

5 [0020] Figs. 6A, 6B and 6C illustrate an example of generating the sequence of bits according to some embodiments of the present disclosure;

[0021] Fig. 7 illustrates a diagram illustrating transmission of the sequence of bits according to some embodiments of the present disclosure;

10 [0022] Figs. 8A and 8B illustrate an example of querying the sequence of bits according to some embodiments of the present disclosure;

[0023] Fig. 9 illustrates a graph showing performance of the proposed solution according to some embodiments of the present disclosure;

[0024] Fig. 10 illustrates a flowchart of a method according to some embodiments of the present disclosure;

15 [0025] Fig. 11 illustrates a flowchart of a method according to some other embodiments of the present disclosure;

[0026] Fig. 12 illustrates a simplified block diagram of an apparatus that is suitable for implementing embodiments of the present disclosure; and

20 [0027] Fig. 13 illustrates a block diagram of an example computer readable medium in accordance with some embodiments of the present disclosure.

[0028] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

DETAILED DESCRIPTION

25 [0029] Principle of the present disclosure will now be described with reference to some example embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones
30 described below.

[0030] In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0031] References in the present disclosure to “one embodiment,” “an embodiment,” “an example embodiment,” and the like indicate that the embodiment described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0032] It shall be understood that although the terms “first” and “second” etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and similarly, a second element could be termed a first element, without departing from the scope of example embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms.

[0033] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of example embodiments. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises”, “comprising”, “has”, “having”, “includes” and/or “including”, when used herein, specify the presence of stated features, elements, and/or components etc., but do not preclude the presence or addition of one or more other features, elements, components and/ or combinations thereof.

[0034] As used in this application, the term “circuitry” may refer to one or more or all of the following:

(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and

(b) combinations of hardware circuits and software, such as (as applicable):

(i) a combination of analog and/or digital hardware circuit(s) with

software/firmware and

(ii) any portions of hardware processor(s) with software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions) and

5 (c) hardware circuit(s) and or processor(s), such as a microprocessor(s) or a portion of a microprocessor(s), that requires software (e.g., firmware) for operation, but the software may not be present when it is not needed for operation.

[0035] This definition of circuitry applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term
10 circuitry also covers an implementation of merely a hardware circuit or processor (or multiple processors) or portion of a hardware circuit or processor and its (or their) accompanying software and/or firmware. The term circuitry also covers, for example and if applicable to the particular claim element, a baseband integrated circuit or processor integrated circuit for a mobile device or a similar integrated circuit in server, a cellular
15 network device, or other computing or network device.

[0036] As used herein, the term “communication network” refers to a network following any suitable communication standards, such as Long Term Evolution (LTE), LTE-Advanced (LTE-A), Wideband Code Division Multiple Access (WCDMA), High-Speed Packet Access (HSPA), Narrow Band Internet of Things (NB-IoT) and so on.
20 Furthermore, the communications between a terminal device and a network device in the communication network may be performed according to any suitable generation communication protocols, including, but not limited to, the first generation (1G), the second generation (2G), 2.5G, 2.75G, the third generation (3G), the fourth generation (4G), 4.5G, the future fifth generation (5G) communication protocols, and/or any other protocols either
25 currently known or to be developed in the future. Embodiments of the present disclosure may be applied in various communication systems. Given the rapid development in communications, there will of course also be future type communication technologies and systems with which the present disclosure may be embodied. It should not be seen as limiting the scope of the present disclosure to only the aforementioned system.

30 **[0037]** As used herein, the term “network device” refers to a node in a communication network via which a terminal device accesses the network and receives services therefrom. The network device may refer to a base station (BS) or an access point (AP), for example, a

node B (NodeB or NB), an evolved NodeB (eNodeB or eNB), a NR NB (also referred to as a gNB), a Remote Radio Unit (RRU), a radio header (RH), a remote radio head (RRH), a relay, a low power node such as a femto, a pico, and so forth, depending on the applied terminology and technology.

5 **[0038]** The term “terminal device” refers to any end device that may be capable of wireless communication. By way of example rather than limitation, a terminal device may also be referred to as a communication device, user equipment (UE), a Subscriber Station (SS), a Portable Subscriber Station, a Mobile Station (MS), or an Access Terminal (AT). The terminal device may include, but not limited to, a mobile phone, a cellular phone, a
10 smart phone, voice over IP (VoIP) phones, wireless local loop phones, a tablet, a wearable terminal device, a personal digital assistant (PDA), portable computers, desktop computer, image capture terminal devices such as digital cameras, gaming terminal devices, music storage and playback appliances, vehicle-mounted wireless terminal devices, wireless endpoints, mobile stations, laptop-embedded equipment (LEE), laptop-mounted equipment
15 (LME), USB dongles, smart devices, wireless customer-premises equipment (CPE), an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a
20 device operating on commercial and/or industrial wireless networks, and the like. In the following description, the terms “terminal device”, “communication device”, “terminal”, “user equipment” and “UE” may be used interchangeably.

[0039] In NR, an asynchronous HARQ protocol is employed for both downlink and uplink. In an asynchronous HARQ protocol, the retransmissions are in principle
25 scheduled similarly to the initial transmissions. The use of an asynchronous uplink protocol, instead of a synchronous one as in LTE, is necessary to support dynamic Time Division Duplex (TDD) where there is no fixed uplink/downlink allocation. It also offers better flexibility in terms of prioritization between data flows and devices, and is beneficial for extension to unlicensed spectrum operation. For such an asynchronous operation, the
30 explicit HARQ process number is also required to signalize for indicating which process is being addressed. NR supports up to 16 HARQ processes, coming at an additional cost of four bits to distinguish the HARQ processes. Having a larger maximum number of HARQ processes than in LTE is motivated by the possibility of remote radio heads, which

incurs a certain front-haul delay, together with the shorter slot durations at high frequencies. It is important that the larger number of maximum HARQ processes does not imply a longer round trip time as not all processes need to be used and it is only an upper limit of the number of processes possible.

5 **[0040]** One additional feature of the HARQ mechanism in NR compared to LTE is the possibility for retransmission of code block groups. This feature can be beneficial for a very large transport block or when a transport block is partially interfered by another preempting transmission. As a part of the channel-coding operation in the physical layer, a transport block is split into one or more code blocks with error-correcting coding applied
10 to each of the code blocks of at most 8448 bits in order to keep the channel-coding complexity reasonable. Thus, even at modest data rates there may be multiple code blocks per transport block, and at Gbps data rates there may be hundreds of code blocks per transport block.

[0041] In many cases, especially if the interference is bursty and hits a small number of
15 Orthogonal Frequency Division Multiple (OFDM) symbols in the slot, only a few of these code blocks in a transport block may be corrupted, while the majority of these code blocks are correctly received. To correctly receive the transport block, it is sufficient to retransmit the erroneous code blocks rather than the whole transport block. However, the control signaling overhead would be too large, if all individual code blocks are addressed
20 by the HARQ mechanism. The signaling overhead of HARQ becomes unsustainable, which will deteriorate for massive connectivity. Therefore, the future development of NR calls for a sophisticated and economic method for signaling of HARQ acknowledgements, which can enable per-code-block retransmission.

[0042] In the asynchronous HARQ protocol, the receiving device feeds back ACK/NACK
25 to the transmitting device. First of all, the transmitting device must determine which HARQ process and which code block a returned acknowledgment is associated with. In case of a small number of code blocks to be indicated, this is can be directly solved by using the explicit HARQ process number and code block number, using the timing of the acknowledgment for association with a certain HARQ process, or using the position of the
30 acknowledgment in the HARQ codebook in case of multiple acknowledgments transmitted at the same time.

[0043] Nevertheless, the above straightforward method is inapplicable to NR given the

unsustainable signaling cost. This is because NR permits one UE to maintain up to 16 HARQ processes per carrier, and each process usually handles hundreds of code blocks. For this reason, in NR, HARQ protocol does some trade-off between performance and signaling cost by configuring per-code-block group (CBG) retransmission. The HARQ acknowledgement only indicates a code block group rather than an individual code block. Thus, a whole CBG including the corrupted code blocks and the correct code blocks is needed to be retransmitted, resulting in the inevitable performance loss in bandwidth efficiency.

[0044] On the other hand, the HARQ mechanism in the MAC layer targets very fast retransmissions. If low latency is important, a large number of HARQ acknowledgments need to be fed back quickly after the end of the downlink slot and uplink slot, which challenges the control channel design. Either positive or negative acknowledgement must be sent for a transport block or code block, no matter what the decoding status is. Taking advantage of the strong forward error-correcting code employed, the probability of receiving an erroneous code block is very low, especially for Ultra Reliability Low Latency Communication (URLLC). The minimum reliability requirement of URLLC is $1-10^{-5}$ success probability of transmitting a layer 2 protocol data unit of 32 bytes within 1 ms in channel quality of coverage edge. This means that a receiving device almost feeds back the message about positive acknowledgement, and few NACKs are conveyed.

[0045] In view of the above, such asymmetry feedback of ACK and NACK can be deliberately exploited to save signaling overhead with an appropriate design. However, conventional methods place less emphasis on this point. The embodiments of the present disclosure attempt to indicate and transmit the HARQ acknowledgements in an integrated way for multiple transmissions. The disclosed signaling method exploits the sporadic nature of NACK signaling and allows for a high-efficient HARQ protocol without the compromise between performance and cost.

[0046] Principle and embodiments of the present disclosure will be described in detail below with reference to the accompanying drawings. Reference is first made to Fig. 1, which illustrates an example communication network in which embodiments of the present disclosure may be implemented. The communication network 100 includes a network device 110 and terminal devices 120-1, 120-2 ... and 120-N (where N is an integer number), which can be collectively referred to as "terminal devices" 120 or individually referred to as a "terminal device" 120.

[0047] The network 100 can provide one or more cells 102 to serve the terminal devices 120. It is to be understood that the number of network devices, terminal devices and/or cells is given for the purpose of illustration without suggesting any limitations to the present disclosure. The communication network 100 may include any suitable number of
5 network devices, terminal devices and/or cells adapted for implementing implementations of the present disclosure.

[0048] In the communication network 100 as shown in FIG. 1, the network device 110 can communicate data and control information to the terminal device 120 and the terminal device 120 can also communication data and control information to the network device 110.

10 A link from the network device 110 to the terminal device 120 is referred to as a downlink (DL), while a link from the terminal device 120 to the network device 110 is referred to as an uplink (UL). In DL, the network device 110 is a transmitting (TX) device (or a transmitter) and the terminal device 120 is a receiving (RX) device (or a receiver). In UL, the terminal device 120 is a TX device (or a transmitter) and the network device 110 is a
15 RX device (or a receiver).

[0049] Communications in the communication network 100 may be implemented according to any proper communication protocol(s), comprising, but not limited to, cellular communication protocols of the first generation (1G), the second generation (2G), the third generation (3G), the fourth generation (4G) and the fifth generation (5G) and on the like,
20 wireless local network communication protocols such as Institute for Electrical and Electronics Engineers (IEEE) 802.11 and the like, and/or any other protocols currently known or to be developed in the future. Moreover, the communication may utilize any proper wireless communication technology, comprising but not limited to: Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA), Time Division
25 Multiple Access (TDMA), Frequency Division Duplex (FDD), Time Division Duplex (TDD), Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiple (OFDM), Discrete Fourier Transform spread OFDM (DFT-s-OFDM) and/or any other technologies currently known or to be developed in the future.

[0050] In communication, a TX device may transmit a transport block including a
30 plurality of code blocks or CBGs to a RX device. For example, in UL, the network device 110 may receive transport blocks from the terminal devices 120-1, 120-2, ..., 120-N. In DL, the terminal device 120 (e.g. the terminal device 120-1) may receive a transport block from the network device 110. The reception state of each code block and/or CBG may be

determined by the RX device and an indication of the reception state may be transmitted to the TX device to indicate the TX device whether retransmit the corresponding code block and/or CBG.

[0051] Conventionally, almost all HARQ protocols adopt separated signaling of HARQ acknowledgements for uplink transmissions. Reference is now made to Fig. 2, which shows a diagram 200 illustrating separated signaling of HARQ acknowledgements. As shown in Fig. 2, a network device, for example, a gNB 210, maintains a plurality of independent HARQ entities 230-1, 230-2, ..., 230-N, each for one of the UEs 220-1, 220-2, ..., 220-N. A HARQ entity decodes the UL transport block (or the code block) and informs the corresponding UE of the outcome of the decoding operation, through separated DL control channels over the radio interface. The HARQ acknowledgements for different UEs 220-1, 220-2, ..., 220-N are separately indicated and signaled from each other. Therefore, the signaling cost are scaled up with the number of UEs and the number of carrier components, as well as the total number of HARQ processes and code blocks.

[0052] For example, in NR standard, the HARQ-related information is included in the user-specific uplink scheduling grant, separately dedicating to each of UEs 220-1, 220-2, ..., 220-N. The scheduling assignment contains the necessary HARQ-related control signaling and transport-block-related information, including: HARQ process number (4 bit), informing the device about the HARQ process to use for soft combining; the CBG transmission indicator (CBGTI, 0, 2, 4, 6, or 8 bit), indicating the code block groups retransmitted (Only present in DCI format 1-1 and only if CBG retransmissions are configured.); new-data indicator (1 bit), indicating whether the grant relates to retransmission of a transport block or transmission of a new transport block.

[0053] Based on such signaling, the so-called CBGs are defined via the explicit indication. If per-CBG retransmission is configured, feedback is provided per CBG and only the erroneously received code block groups are retransmitted. This can consume less resource than retransmitting the whole transport block, thereby reaching a compromise between performance and cost.

[0054] In addition, the separated signaling method as shown in Fig. 2 has less flexibility. The control-channel resource should be reserved for the mentioned HARQ-related and transport-block-related information, no matter what decoding status the code blocks have. To support per-code-block retransmission, the least signaling overhead (in bit) required by

the separated signaling amounts to the total number of UL code blocks from all the UEs 220-1, 220-2, ..., 220-N.

[0055] Therefore, the embodiments of the present disclosure propose a solution for integrating signaling of HARQ acknowledgements. In the solution, a sequence of bits is generated by the RX device to indicate the HARQ-related information about a plurality of code blocks or CBGs in a joint and implicit manner. The RX device may transmit to one or more TX device the sequence of bits, from which the one or more TX device may determine the HARQ-related information about the code blocks or CBGs. When the RX device is a network device and the one or more TX device comprises a plurality of terminal devices, the sequence of bits may be broadcast over the radio interface. In this way, per-code-block retransmission or per CBG retransmission is achieved with smaller signaling overhead.

[0056] Reference is now made to Fig. 3, which illustrates a flowchart illustrating an example process 300 for integrated signaling of HARQ acknowledgements according to some embodiments of the present disclosure. For the purpose of discussion, the process 300 will be described with reference to Fig. 1. The process 300 may involve the network device 110 and one or more of the terminal devices 120 as illustrated in Fig. 1.

[0057] In the process 300, the terminal device 120 transmits 305 a transmission block to the network device 110. For example, the terminal device 120 may transmit during a HARQ process a transport block including a plurality of transmission blocks to the network device 110. As used herein, the term “transmission block” refers to a data unit of which the reception state can be determined by the RX device, for example based on CRC. In some example embodiments, the transmission block may refer to a code block. In some other example embodiments, the transmission block may refer to a CBG. It is to be understood that the embodiments of the present disclosure may be applied to data units with other size or granularity as long as reception states of such data units can be determined individually.

[0058] Although only one terminal device 120 is shown in Fig. 3, it is to be understood that the process 300 may involve more than one terminal devices, for example all or some of the terminal device 120-1, 120-2, ..., 120-N. As such, the network device 110 receives a plurality of transmission blocks at least from the terminal device 120. In some example embodiments, the plurality of transmission blocks may be received from a single terminal

device 120. In some example embodiments, the plurality of transmission blocks may be received from a plurality of terminal devices, for example, all or some of the terminal device 120-1, 120-2...120-N.

[0059] The network device 110 determines 310 reception states of the plurality of transmission blocks received from at least one terminal device 120. For example, the network device 110 may detect whether there is an error in decoding each transmission block of a transport block. Then, the network device 110 generates 315 a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence. That is, the sequence of bits indicates the reception states of the plurality of transmission blocks in an integrated way.

[0060] To better understand the integrated way proposed in the disclosure, reference is now made to Fig. 4. Fig. 4 illustrates a diagram 400 illustrating integrated signaling of HARQ acknowledgements according to some embodiments of the present disclosure. In the example architecture depicted in Fig. 4, a randomized data structure based on a Bloom filter 450 is introduced and optimized. The network device 110 serves the terminal devices 120-1, 120-2, ..., 120-N with UL transmissions and maintains HARQ entities 430-1, 430-2, ..., 430-N, each handling the HARQ processes for the corresponding one of the terminal devices 120-1, 120-2, ..., 120-N.

[0061] In contrast with the separated signaling shown in Fig. 2, all the HARQ entities 430-1, 430-2, ..., 430-N share the same Bloom filter 450. In some example embodiments, the Bloom filter may be designed as a filter of NACK, which is configured to represent a set of NACK information from all or some of HARQ entities 430-1, 430-2, ..., 430-N. The Bloom filter 450 may generate the sequence of bits, which indicates the composited information of NACKs corresponding to the plurality of transmission blocks, for example a plurality of code blocks.

[0062] In the example shown in Fig. 4, only one Bloom filter 450 is maintained by the network device 110 for the plurality of terminal devices 120-1, 120-2, ..., 120-N to generate the sequence of bits. Alternatively or additionally, the network device 110 may maintain a Bloom filter for each of the plurality of terminal devices 120-1, 120-2, ..., 120-N. In such cases, the sequence of bits may be generated for each of the terminal devices 120 and integrally indicate the reception states of a plurality of transmission blocks

from the corresponding terminal device 120.

[0063] To understand the mapping of a certain transmission block to the one or more bit in the sequence, now reference is made to Fig. 5. Fig. 5 illustrates a diagram 500 illustrating an example process of HARQ-related information according to some embodiments of the present disclosure. As shown in Fig. 5, the sequence 550 of bits generated by the network device 110 (e.g., by the Bloom filter 450) may have m bits. All of the m bits are initially assigned with a first value, for example, "0".

[0064] To map the transmission block 501, an identification generator 510 may be used. The identification generator 510 may perform bijective mapping such that a transmission block associated with a HARQ process of a particular terminal device 120 can be indexed by a unique identification, e.g., a global ID number.

[0065] In the case where one Bloom filter is maintained for a plurality of terminal devices 120 (such as the example shown in Fig. 4), the identification generator 510 may generate an unique identification 520 of the transmission block 501 based on an identification of the terminal device 120 from which the transmission block 501 is received, an identification of a HARQ process during which the transmission block 501 is received, and an identification of the transmission block 501 used to distinguish the transmission block 501 from other transmission blocks of the terminal device 120. In other words, the unique identification 520 of the transmission block 501 is generated based on a set of local identifications associated with the transmission block 501. As an example, if the transmission block 501 is a code block received from the terminal device 120-1 during a HARQ process, then the identification of the terminal device 120-1, the local number of the HARQ process and the local number of the code block with respect to the terminal device 120-1 may be used to generate the unique identification 520.

[0066] In the case where a Bloom filter is maintained by each HARQ entity for a corresponding terminal device 120, the identification generator 510 may generate an unique identification 520 of the transmission block 501 based on an identification of a HARQ process during which the transmission block 501 is received and an identification of the transmission block 501 used to distinguish the transmission block 501 from other transmission blocks of the terminal device 120.

[0067] In the example shown in Fig. 4, for each of the HARQ entities 430-1, 430-2, ..., 430-N, if a transmission block (for example, a code block) does not pass CRC, the unique

identification of the erroneous transmission block may be fed into the Bloom filter 450 of NACK. It is to be understood that both the network device 110 and the terminal device 120 employ the same identification generator 510 or apply the same generating rule to generate the unique identification of the transmission block. The identification generator
 5 510 may be implemented in a variety of ways and the scope of the present disclosure is not limited in this regard.

[0068] Then, positions of the one or more bits in the sequence 550 that correspond to the transmission block 501 may be determined by hashing the unique identification 520. For example, k independent uniformly random hash functions $\{f_i(\cdot)|i=1,2,\dots,k\}$ may be
 10 used. Each of the hash functions 530-1, 530-2, ..., 530-k maps a unique identification into the range of $\{0,1,2,\dots,m-1\}$. Each element of the range indicates a position in the sequence 550 of bits. It is to be understood that the hash functions should be known by both the network device 110 and all the terminal devices 120.

[0069] For the example shown in Fig. 5, it is assumed that the unique identification 520 of
 15 the transmission block 501 is x , the computation of hash functions 530-1, 530-2, ..., 530-k may generate a set $\{f_i(x)|i=1,2,\dots,k\}$ indicating the k positions in the sequence 550. If x indexes an erroneous transmission block, the $f_i(x)$ -th bit in the sequence 550, for $i=1,2,\dots,k$, may be assigned with a second value, for example, "1". It is to be understood that a particular bit may be set to "1" multiple times, but only the first change is
 20 in effect. After performing the same operation for all erroneous transmission block, the resulting sequence 550 may indicate all NACK information in an integrated fashion.

[0070] Now reference is made back to Fig. 3. After generating the sequence of bits, for example after mapping all the transmission blocks with NACK, the network device 110 transmits
 25 320 the resulting sequence of bits to the terminal device 120 as indication of the reception state of the plurality of transmission blocks. In the example embodiments where one Bloom filter is maintained for a plurality of terminal devices 120 (such as the example shown in Fig. 4), the network device 110 may broadcast the sequence of bits over a DL control channel such that each of the terminal devices 120 in the serving cell 102 may receive at least one portion of the sequence of bits. In the example embodiments where a
 30 Bloom filter is maintained by each HARQ entity for a corresponding terminal device 120, the sequence of bits may be transmitted over a dedicated DL control channel to the

corresponding terminal device 120.

[0071] Upon receiving the at least one portion of the sequence of bits, the terminal device 120 may determine 325 the reception state of the transmission block which has been transmitted previously. For example, the terminal device 120 may first use the identification generator 510 as described above to generate the unique identification (for example, represented as y) of a certain transmission block. Then, the hash functions $\{f_i(\cdot) | i=1,2,\dots,k\}$ may be applied to the unique identification y and a set of $f_i(y)$ where $i=1,2,\dots,k$ may be generated to indicate the k positions in the sequence.

[0072] If all the set of bits $f_i(y)$, for $i=1,2,\dots,k$, have a second value, for example a value of "1", the terminal device 120 may determine that a failure in receiving the transmission block indexed by y occurs, otherwise the terminal device 120 may determine that the transmission block indexed by y is correctly received by the network device 110. If the terminal device 120 determines that the failure in receiving the transmission block indexed by y occurs, the terminal device 120 may retransmit this transmission block, for example in the next slot.

[0073] In some example embodiments, the terminal device 120 may determine a duration t since the transmission block is transmitted 305 and determine whether the duration exceeds a time threshold T_{\max} for an indication of the reception state. If the duration t is below the time threshold T_{\max} , the terminal device 120 may determine the reception state of the transmission block based on the received sequence of bits.

[0074] An example of general process of integrated signaling of HARQ acknowledgements is described with reference to Fig. 3. Although the example process 300 is described with respect to UL transmission, the integrated signaling may also be applied to the DL transmission. In such cases, a sequence of bits which indicates the reception states of a plurality of DL transmission blocks may be generated by the terminal device 120 and transmitted to the network device 110.

[0075] In the example embodiments of the present disclosure, the HARQ acknowledgements for a large number of transmission blocks (for example, code blocks) can be fed back to the TX device in an integrated way and the signaling overhead can thus be reduced significantly. In this way, per-code-block or per CBG retransmission can be accomplished.

[0076] Now a specific example implementation is described with reference to Figs. 6A, 6B, 6C, 7, 8A and 8B. Figs. 6A, 6B and 6C illustrate an example of generating the sequence of bits according to some embodiments of the present disclosure. As shown in Fig. 6A, the sequence 650 consists of m bits, which are indexed by 0, 1, 2, ..., $m-1$, respectively. Each bit in the sequence 650 is initially assigned with a value of "0" by the network device 110.

[0077] As shown in Fig. 6B, the network device 110 may determine that a failure in receiving the code block 601 occurs and generate the unique identification ID_1 of the code block 601, for example as discussed above with reference to Fig. 5. The hash functions 530-1, 530-2, ..., 530- k are then applied to the unique identification ID_1 . As shown in Fig. 6B, since $f_1(ID_1) = 2$, $f_2(ID_1) = m - 6$, $f_k(ID_1) = 4$, the network device 110 may assign the value "1" to bits 2, 4, $m-6$.

[0078] As shown in Fig. 6C, the network device 110 may determine that a failure in receiving the code block 602 occurs and generate the unique identification ID_2 of the code block 602. The hash functions 530-1, 530-2, ..., 530- k are then applied to the unique identification ID_2 . As shown in Fig. 6B, since $f_1(ID_2) = 0$, $f_2(ID_2) = m - 5$ and $f_k(ID_2) = 2$, the network device 110 may assign the value "1" to bits 0, 2, $m-5$. It is to be noted that in this example, the value of bit 2 is set to be "1" twice and only the first time is in effect.

[0079] After the generation of the sequence 650 of bits, the network device 110 may transmit the sequence 650 to the terminal devices 120. Reference is now made to Fig. 7, which illustrates a diagram 700 illustrating transmission of the sequence of bits according to some embodiments of the present disclosure. As shown in Fig. 7, the network device 110 may broadcast the sequence 750 of bits over the DL broadcast control channel. To quickly feedback the NACK information of all erroneous code blocks received within the current slot, the DL broadcast control channel is configured at the end of each slot. As shown in Fig. 7, the dedicated resource 710 may be configured for the DL broadcast control channel to transmit the sequence 750 of bits.

[0080] As such, each terminal device 120 may obtain the sequence 750 of bits by decoding the DL control channel and determine whether the code blocks having been transmitted is successfully received or not. Alternatively, each terminal device 120 may decode only a portion of the DL control channel which is allocated for a subset of bits in the

sequence 750 corresponding to one or more code blocks transmitted by itself. In such a case, the terminal device 120 may first determine the subset of bits corresponding to the one or more code blocks and only decode the portion allocated for the subset of bits.

[0081] Figs. 8A and 8B illustrate an example of querying the sequence 750 of bits according to some embodiments of the present disclosure. It is to be understood that the sequence 750 as shown in Figs. 7, 8A and 8B is shadowed and has a different reference sign with the sequence 650 as shown in Figs. 6A, 6B and 6C. This take into account of potential errors in transmitting or receiving the sequence 650, which does not affect the principle of the present disclosure.

[0082] As shown in Fig. 8A, for the code block 601, the terminal device 120 may generate the unique identification ID_1 of this code block 601, for example, by using the generator 510 as discussed with reference to Fig. 5. The hash functions 530-1, 530-2, ..., 530-k are then applied to the unique identification ID_1 . Similar as shown in Fig. 6B, the outcome of hashing the unique identification ID_1 is $f_1(ID_1) = 2$, $f_2(ID_1) = m - 6$, $f_k(ID_1) = 4$.

The terminal device 120 checks the values of bits 2, 4, m-6. Since all of the bits 2, 4, m-6 have the value of "1", the terminal device 120 may determine that a failure occurs in receiving the code block 601 by the network device 110 and retransmit the code block 601 to the network device 110.

[0083] As shown in Fig. 8B, for the code block 803, the terminal device 120 may generate the unique identification ID_3 of this code block 803, for example, by using the generator 510. The hash functions 530-1, 530-2, ..., 530-k are then applied to the unique identification ID_3 . The outcome of hashing the unique identification ID_3 is $f_1(ID_3) = 2$, $f_2(ID_3) = 3$, $f_k(ID_3) = 4$. The terminal device 120 checks the values of bits 2, 3, 4. Since the value of bit 3 is "0", the terminal device 120 may determine that the code block 803 is successfully received by the network device 110 and thus no retransmission is needed.

[0084] It is to be understood that the example implementation is given for purpose of illustration without any limitation. Additionally, the network device 110 and the terminal devices 120 have the knowledge about the identification generator, the hash functions and the size of the sequence of bits, as well as the DL broadcast control channel.

[0085] In some example embodiments, the number of bits in the sequence and the number of hash functions for hashing the unique identification may be fixed. In some example embodiments, the number of bits in the sequence and the number of hash functions for hashing the unique identification may be dimensioned. Such example embodiments are now described in detail.

[0086] The above proposed solution for integrated signaling of HARQ NACK only suffers one-side error. Specifically, the probability of false ACK, where a transmission block is declared to be correct when it is not, is zero. This means that any erroneous transmission blocks may not be omitted at all. Such a property of robustness is beneficial for the retransmission design.

[0087] It sometimes suffers false NACK, where a transmission block is declared to be erroneous when it is not. All the k bits corresponding to one correct transmission block may be set to "1" by other erroneous transmission blocks. It is worthwhile to be noted that the probability of false NACK can be reduced to an acceptable (approximating to zero) rate by dimensioning the Bloom filter of NACK, for example, dimensioning the number of bits in the sequence and the number of hash functions.

[0088] The probability of a false NACK for a correct transmission block (which is referred to as false NACK probability), can be calculated in a straightforward fashion, given that the hash functions are random. It is assumed that the network device receives total N transmission blocks from one or more terminal devices within one slot, each of which suffers error independently with a probability P_e . After the unique identifications of all M erroneous transmission blocks are hashed into the sequence of bits, the probability that a specific bit still has a value of "0", denoted by P , can be calculated by

$$P(M) = \left(1 - \frac{1}{m}\right)^{kM} \approx e^{-kM/m} \quad (1)$$

where $P(M)$ is random depending on a binominal random variable M such that

$$\Pr\{M = i\} = \binom{N}{i} P_e^i (1 - P_e)^{N-i}, \quad i = 0, 1, \dots, N \quad (2).$$

[0089] Let q be the fraction of bits that are set to be "0" after all erroneous transmission

blocks are hashed into the Bloom filter. It is possible to prove that q is very strongly concentrated around its expected value, i.e.

$$\begin{aligned} q &\approx E\{p(M) \times 1 + (1 - p(M)) \times 0\} \\ &= E\{p(M)\} \\ &= \sum_{i=0}^N \binom{N}{i} P_e^i (1 - P_e)^{N-i} e^{-ki/m} \end{aligned} \quad (3).$$

[0090] In practical engineering, it is difficult to apply the direct calculation to optimize the Bloom filter of NACK. In the following, a lower bound of q is used for easing the practical optimization. It can be proved that the function $e^{-kM/m}$ is convex with respect to M . According to Jensen's Inequality, the following equation applies:

$$q = E\{p(M)\} \geq e^{-kE\{M\}/m} = e^{-kNP_e/m} \quad (4).$$

[0091] Thus, the false NACK probability can be approximately characterized by:

$$P_{\text{fNACK}} \approx (1 - q)^k \leq \left(1 - e^{-kNP_e/m}\right)^k \quad (5).$$

It is to be noted that testing whether a NACK associated with a correct transmission block is transmitted, for a position in the sequence given by any of the k hash functions, the probability that the bit is assigned with "1" is $1 - q$. Therefore, the probability that all the bits corresponding to the k hash functions are assigned with "1" is $(1 - q)^k$.

[0092] The upper bound of the false NACK probability can be minimized by choosing an appropriate number of hash functions for a given NP_e/m . It can be readily shown that the minimum false NACK reaches to

$$P_{\text{fNACK, min}} = (0.5)^{m \ln 2 / NP_e} \approx (0.6185)^{m / NP_e} \quad (6)$$

as long as $k = m \ln 2 / NP_e$. This also means that the false NACK probability can drop down to less than a given tolerance ε if the required size of the sequence of bits satisfies

$$m \geq NP_e \frac{\log_2(1/\varepsilon)}{\ln 2} \approx NP_e \cdot 1.44 \log_2(1/\varepsilon) \quad (7).$$

[0093] The required overhead of the integrated signaling just linearly scales up with a very small number $1.44P_e \log_2(1/\varepsilon)$, considering that P_e is on the order of 10^{-5} .

Consequently, the optimal number of hash functions can be determined by $k = \log_2(1/\varepsilon)$.

[0094] As such, the length of the sequence of bits and the number of the hash functions may be dimensioned. The network device 110 may determine a failure rate P_e of transmission blocks. The failure rate P_e may be predetermined for example at system design level. The failure rate P_e may be determined based on the reception states of transmission blocks which have been received by the network device 110.

[0095] The network device 110 may determine a tolerance of false rate for the indication of the reception states, for example, a tolerance ε of the false NACK probability. The tolerance ε of false rate may be predetermined for example at system design level. The network device 110 may then determine a length of the sequence of bits, based on the failure rate P_e , the tolerance ε of false rate and the number of the plurality of transmission blocks. For example, the length of the sequence of bits may be determined as $\lceil 1.44NP_e \log_2(1/\varepsilon) \rceil$, where $\lceil x \rceil$ denotes the minimum integer more than x .

[0096] The network device 110 may further determine the number of hash functions for hashing the unique identification based on the tolerance of false rate. For example, the number of hash functions may be determined as $k = \lfloor \log_2(1/\varepsilon) \rfloor$, where $\lfloor x \rfloor$ denotes the maximum integer less than x .

[0097] In some example embodiments, the network device 110 may further transmit the length of the sequence of bits and the number of hash functions to the terminal device 120. For example, the network device 110 may broadcast indications of the length of the sequence of bits and the number of hash functions such that all the terminal devices 120 in the serving cell 102 may have the knowledge about the length of the sequence of bits and the number of hash functions.

[0098] The proposed integrated signaling solution exhibits zero false ACK probability and negligible false NACK probability ($10^{-10} \sim 10^{-15}$) with ultra-small signaling overhead. The above analysis has shown that a signaling overhead of just $\lceil 1.44NP_e \log_2(1/\varepsilon) \rceil$ bits is required to achieve a false probability less than ε , for given total N transmission blocks with failure rate P_e to be addressed by the HARQ process. In other words, the amount of signaling overhead used for HARQ acknowledgements can be reduced by a factor of

$$1.44P_e \log_2(1/\varepsilon).$$

[0099] Fig. 9 illustrates a graph 900 showing performance of the proposed solution according to some embodiments of the present disclosure. As shown in Fig. 9, the reduction factor varies with the failure rate P_e and the tolerance ε of false rate. It can be seen that the proposed solution can decrease the signaling overhead by 2~3 orders of magnitude at the false NACK probability of 10^{-10} ~ 10^{-15} . This means that the proposed solution is amenable to massive access with per-code block requesting HARQ.

[00100] More details of the example embodiments in accordance with the present disclosure will be described with reference to Figs. 10-11.

10 [00101] Fig. 10 shows a flowchart of an example method 1000 according to some example embodiments of the present disclosure. The method 1000 can be implemented at a device e.g. at the network device 110 as shown in Fig. 1. For the purpose of discussion, the method 1000 will be described with reference to Fig. 1.

[00102] At block 1010, the network device 110 determine reception states of a plurality of transmission blocks received from at least one terminal device 120. At block 1020, the network device 110 generates a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence. At block 1040, the network device 110 transmits the sequence of bits to the at least one terminal device 120 as indication of the reception states.

[00103] In some example embodiments, generating the sequence of bits comprises: assigning a first value to bits in the sequence; and in response to a failure in receiving a first transmission block of the plurality of transmission blocks, assigning a second value to a first subset of bits in the sequence that are corresponding to the first transmission block, the second value being different from the first value.

[00104] In some example embodiments, the method 1000 further comprises: in response to a failure in receiving a second transmission block of the plurality of transmission blocks, assigning the second value to a second subset of bits in the sequence that are corresponding to the second transmission block, the second subset of bits being at least partially different from the first subset of bits.

[00105] In some example embodiments, assigning the second value to the first subset of

bits that are corresponding to the first transmission block comprises: obtaining a unique identification of the first transmission block; and determining positions of the first subset of bits in the sequence by hashing the unique identification.

5 [00106] In some example embodiments, obtaining the unique identification of the first transmission block comprises determining the unique identification of the first transmission block based on at least one of: an identification of a terminal device 120 from which the first transmission block is received; an identification of a Hybrid Automatic Repeat reQuest process during which the first transmission block is received; and an identification of the first transmission block used to distinguish the first transmission block from other
10 transmission blocks of the terminal device 120.

[00107] In some example embodiments, the method 1000 further comprises: determining a failure rate of transmission blocks which have been received by the network device 110; determining a tolerance of false rate for the indication of the reception states; determining a length of the sequence of bits, based on the failure rate, the tolerance of false rate and the
15 number of the plurality of transmission blocks; and determining the number of hash functions for hashing the unique identification based on the tolerance of false rate.

[00108] In some example embodiments, the method 1000 further comprises: transmitting the length of the sequence of bits and the number of hash functions to the at least one terminal device 120.

20 [00109] In some example embodiments, the at least one terminal device 120 comprises a plurality of terminal devices.

[00110] Fig. 11 shows a flowchart of an example method 1100 according to some example embodiments of the present disclosure. The method 1100 can be implemented at a device e.g. at the terminal device 120 as shown in Fig. 1. For the purpose of discussion, the
25 method 1100 will be described with reference to Fig. 1.

[00111] At block 1110, the terminal device 120 transmits a transmission block to a network device 110, the network device 110 receiving a plurality of transmission blocks at least from the terminal device 120. At block 1120, the terminal device 120 receives at least one portion of a sequence of bits from the network device 110, each of the plurality of
30 transmission blocks corresponding to one or more bits in the sequence. At block 1130, the terminal device 120 determines a reception state of the transmission block based on the at least one portion of the sequence of bits.

[00112] In some example embodiments, determining the reception state of the transmission block comprises: determining a subset of bits in the at least one portion of the sequence that are corresponding to the transmission block; determining whether the subset of bits comprises a bit of a first value; and in response to absence of the bit of the first value,
5 determining that a failure in receiving the transmission block by the network device 110 occurs.

[00113] In some example embodiments, the method 1100 further comprises: in response to a determination that the failure in receiving the transmission block by the network device 110 occurs, retransmitting the transmission block to the network device 110.

10 [00114] In some example embodiments, determining a subset of bits in the sequence that are corresponding to the transmission block comprises: obtaining a unique identification of the transmission block; and determining positions of the subset of bits in the sequence by hashing the unique identification.

[00115] In some example embodiments, obtaining the unique identification of the transmission block comprises determining the unique identification of the transmission block based on at least one of: an identification of the terminal device 120; an identification of a Hybrid Automatic Repeat reQuest process during which the transmission block is transmitted; and an identification of the transmission block used to distinguish the transmission block from other transmission blocks of the terminal device 120.

20 [00116] In some example embodiments, the method 1100 further comprises: receiving, from the network device 110, a length of the sequence of bits and the number of hash functions for hashing the unique identification.

[00117] In some example embodiments, the method 1100 further comprises: determining a duration since the transmission block is transmitted; determining whether the duration exceeds a time threshold for an indication of the reception state; and in response to a
25 determination that the duration is below the time threshold, determining the reception state of the transmission block based on the sequence of bits.

[00118] In some example embodiments, an apparatus capable of performing the method 1000 may comprise means for performing the respective steps of the method 1000. The means may be implemented in any suitable form. For example, the means may be
30 implemented in a circuitry or software module.

[00119] In some example embodiments, the apparatus comprises: means for determining

reception states of a plurality of transmission blocks received from at least one second device; means for generating a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and means for transmitting the sequence of bits to the at least one second device as indication of the reception states.

[00120] In some example embodiments, the means for generating the sequence of bits comprises: means for assigning a first value to bits in the sequence; and means for in response to a failure in receiving a first transmission block of the plurality of transmission blocks, assigning a second value to a first subset of bits in the sequence that are corresponding to the first transmission block, the second value being different from the first value.

[00121] In some example embodiments, the apparatus further comprises: means for in response to a failure in receiving a second transmission block of the plurality of transmission blocks, assigning the second value to a second subset of bits in the sequence that are corresponding to the second transmission block, the second subset of bits being at least partially different from the first subset of bits.

[00122] In some example embodiments, the means for assigning the second value to the first subset of bits that are corresponding to the first transmission block comprises: means for obtaining a unique identification of the first transmission block; and means for determining positions of the first subset of bits in the sequence by hashing the unique identification.

[00123] In some example embodiments, the means for obtaining the unique identification of the first transmission block comprises means for determining the unique identification of the first transmission block based on at least one of: an identification of a second device from which the first transmission block is received; an identification of a Hybrid Automatic Repeat reQuest process during which the first transmission block is received; and an identification of the first transmission block used to distinguish the first transmission block from other transmission blocks of the second device.

[00124] In some example embodiments, the apparatus further comprises: means for determining a failure rate of transmission blocks which have been received by the first device; means for determining a tolerance of false rate for the indication of the reception states; means for determining a length of the sequence of bits, based on the failure rate, the

tolerance of false rate and the number of the plurality of transmission blocks; and means for determining the number of hash functions for hashing the unique identification based on the tolerance of false rate.

5 [00125] In some example embodiments, the apparatus further comprises: means for transmitting the length of the sequence of bits and the number of hash functions to the at least one second device.

10 [00126] In some example embodiments, an apparatus capable of performing the method 1100 may comprise means for performing the respective steps of the method 1100. The means may be implemented in any suitable form. For example, the means may be implemented in a circuitry or software module.

15 [00127] In some example embodiments, the apparatus comprises: means for transmitting a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device; means for receiving at least one portion of a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and means for determining a reception state of the transmission block based on the at least one portion of the sequence of bits.

20 [00128] In some example embodiments, the means for determining the reception state of the transmission block comprises: means for determining a subset of bits in the at least one portion of the sequence that are corresponding to the transmission block; means for determining whether the subset of bits comprises a bit of a first value; and means for in response to absence of the bit of the first value, determining that a failure in receiving the transmission block by the first device occurs.

25 [00129] In some example embodiments, the apparatus further comprises: means for in response to a determination that the failure in receiving the transmission block by the first device occurs, retransmitting the transmission block to the first device.

[00130] In some example embodiments, the means for determining a subset of bits in the sequence that are corresponding to the transmission block comprises: means for obtaining a unique identification of the transmission block; and means for determining positions of the subset of bits in the sequence by hashing the unique identification.

30 [00131] In some example embodiments, the means for obtaining the unique identification of the transmission block comprises means for determining the unique identification of the transmission block based on at least one of: an identification of the second device; an

identification of a Hybrid Automatic Repeat reQuest process during which the transmission block is transmitted; and an identification of the transmission block used to distinguish the transmission block from other transmission blocks of the second device.

5 [00132] In some example embodiments, the apparatus further comprises: means for receiving, from the first device, a length of the sequence of bits and the number of hash functions for hashing the unique identification.

10 [00133] In some example embodiments, the apparatus further comprises: means for determining a duration since the transmission block is transmitted; means for determining whether the duration exceeds a time threshold for an indication of the reception state; and means for in response to a determination that the duration is below the time threshold, determining the reception state of the transmission block based on the sequence of bits.

15 [00134] Fig. 12 is a simplified block diagram of a device 1200 that is suitable for implementing embodiments of the present disclosure. The device 1200 may be provided to implement the communication device, for example the terminal devices 120 or the network device 110 as shown in Fig. 1. As shown, the device 1200 includes one or more processors 1210, one or more memories 1220 coupled to the processor 1210, and one or more communication modules 1240 coupled to the processor 1210.

20 [00135] The communication module 1240 is for bidirectional communications. The communication module 1240 has at least one antenna to facilitate communication. The communication interface may represent any interface that is necessary for communication with other network elements.

25 [00136] The processor 1210 may be of any type suitable to the local technical network and may include one or more of the following: general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on multicore processor architecture, as non-limiting examples. The device 1200 may have multiple processors, such as an application specific integrated circuit chip that is slaved in time to a clock which synchronizes the main processor.

30 [00137] The memory 1220 may include one or more non-volatile memories and one or more volatile memories. Examples of the non-volatile memories include, but are not limited to, a Read Only Memory (ROM) 1224, an electrically programmable read only memory (EPROM), a flash memory, a hard disk, a compact disc (CD), a digital video disk (DVD), and other magnetic storage and/or optical storage. Examples of the volatile

memories include, but are not limited to, a random access memory (RAM) 1222 and other volatile memories that will not last in the power-down duration.

[00138] A computer program 1230 includes computer executable instructions that are executed by the associated processor 1210. The program 1230 may be stored in the ROM 1220. The processor 1210 may perform any suitable actions and processing by loading the program 1230 into the RAM 1220.

[00139] The embodiments of the present disclosure may be implemented by means of the program 1230 so that the device 1200 may perform any process of the disclosure as discussed with reference to Figs. 10 to 11. The embodiments of the present disclosure may also be implemented by hardware or by a combination of software and hardware.

[00140] In some embodiments, the program 1230 may be tangibly contained in a computer readable medium which may be included in the device 1200 (such as in the memory 1220) or other storage devices that are accessible by the device 1200. The device 1200 may load the program 1230 from the computer readable medium to the RAM 1222 for execution. The computer readable medium may include any types of tangible non-volatile storage, such as ROM, EPROM, a flash memory, a hard disk, CD, DVD, and the like. Fig. 13 shows an example of the computer readable medium 1300 in form of CD or DVD. The computer readable medium has the program 1230 stored thereon.

[00141] Generally, various embodiments of the present disclosure may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. Some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device. While various aspects of embodiments of the present disclosure are illustrated and described as block diagrams, flowcharts, or using some other pictorial representations, it is to be understood that the block, apparatus, system, technique or method described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

[00142] The present disclosure also provides at least one computer program product tangibly stored on a non-transitory computer readable storage medium. The computer program product includes computer-executable instructions, such as those included in program modules, being executed in a device on a target real or virtual processor, to carry

out the method 1000 or 1100 as described above with reference to Figs. 10-11. Generally, program modules include routines, programs, libraries, objects, classes, components, data structures, or the like that perform particular tasks or implement particular abstract data types. The functionality of the program modules may be combined or split between
5 program modules as desired in various embodiments. Machine-executable instructions for program modules may be executed within a local or distributed device. In a distributed device, program modules may be located in both local and remote storage media.

[00143] Program code for carrying out methods of the present disclosure may be written in any combination of one or more programming languages. These program codes may be
10 provided to a processor or controller of a general purpose computer, special purpose computer, or other programmable data processing apparatus, such that the program codes, when executed by the processor or controller, cause the functions/operations specified in the flowcharts and/or block diagrams to be implemented. The program code may execute entirely on a machine, partly on the machine, as a stand-alone software package, partly on
15 the machine and partly on a remote machine or entirely on the remote machine or server.

[00144] In the context of the present disclosure, the computer program codes or related data may be carried by any suitable carrier to enable the device, apparatus or processor to perform various processes and operations as described above. Examples of the carrier include a signal, computer readable medium, and the like.

[00145] The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable medium may include but not
20 limited to an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of the computer readable storage medium would include an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access
25 memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.

[00146] Further, while operations are depicted in a particular order, this should not be
30 understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable

results. In certain circumstances, multitasking and parallel processing may be advantageous. Likewise, while several specific implementation details are contained in the above discussions, these should not be construed as limitations on the scope of the present disclosure, but rather as descriptions of features that may be specific to particular
5 embodiments. Certain features that are described in the context of separate embodiments may also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment may also be implemented in multiple embodiments separately or in any suitable sub-combination.

[00147] Although the present disclosure has been described in languages specific to
10 structural features and/or methodological acts, it is to be understood that the present disclosure defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

WHAT IS CLAIMED IS:

1. A first device, comprising:

at least one processor; and

at least one memory including computer program codes;

5 the at least one memory and the computer program codes are configured to, with the at least one processor, cause the first device at least to:

determine reception states of a plurality of transmission blocks received from at least one second device;

10 generate a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and

transmit the sequence of bits to the at least one second device as indication of the reception states.

15 2. The first device of Claim 1, wherein the sequence of bits is generated by:

assigning a first value to bits in the sequence; and

19 in response to a failure in receiving a first transmission block of the plurality of transmission blocks, assigning a second value to a first subset of bits in the sequence that are corresponding to the first transmission block, the second value being different from the
20 first value.

3. The first device of Claim 2, wherein the first device is further caused to:

24 in response to a failure in receiving a second transmission block of the plurality of transmission blocks, assign the second value to a second subset of bits in the sequence that are corresponding to the second transmission block, the second subset of bits being at least
25 partially different from the first subset of bits.

4. The first device of Claim 2, wherein the first subset of bits is determined by:

obtaining a unique identification of the first transmission block; and

30 determining positions of the first subset of bits in the sequence by hashing the unique identification.

5. The first device of Claim 4, wherein the unique identification of the first

transmission block is determined based on at least one of:

an identification of a second device from which the first transmission block is received;

an identification of a Hybrid Automatic Repeat reQuest process during which the first transmission block is received; and

an identification of the first transmission block used to distinguish the first transmission block from other transmission blocks of the second device.

6. The first device of Claim 4, wherein the first device is further caused to:

determine a failure rate of transmission blocks which have been received by the first device;

determine a tolerance of false rate for the indication of the reception states;

determine a length of the sequence of bits, based on the failure rate, the tolerance of false rate and the number of the plurality of transmission blocks; and

determine the number of hash functions for hashing the unique identification based on the tolerance of false rate.

7. The first device of Claim 6, wherein the first device is further caused to:

transmit the length of the sequence of bits and the number of hash functions to the at least one second device.

8. The first device of Claim 1, wherein the first device comprises a network device and the at least one second device comprises a plurality of terminal devices.

9. A second device, comprising:

at least one processor; and

at least one memory including computer program codes;

the at least one memory and the computer program codes are configured to, with the at least one processor, cause the second device at least to:

transmit a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device;

receive at least one portion of a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and

determine a reception state of the transmission block based on the at least one

portion of the sequence of bits.

10. The second device of Claim 9, wherein the reception state of the transmission block is determined by:

5 determining a subset of bits in the at least one portion of the sequence that are corresponding to the transmission block;

determining whether the subset of bits comprises a bit of a first value; and

in response to absence of the bit of the first value, determining that a failure in receiving the transmission block by the first device occurs.

10

11. The second device of Claim 10, wherein the second device is further caused to: in response to a determination that the failure in receiving the transmission block by the first device occurs, retransmitting the transmission block to the first device.

12. The second device of Claim 10, wherein the subset of bits in the sequence that are corresponding to the transmission block are determined by:

obtaining a unique identification of the transmission block; and

determining positions of the subset of bits in the sequence by hashing the unique identification.

20

13. The second device of Claim 12, wherein the unique identification of the transmission block is determined based on at least one of:

an identification of the second device;

25 an identification of a Hybrid Automatic Repeat reQuest process during which the transmission block is transmitted; and

an identification of the transmission block used to distinguish the transmission block from other transmission blocks of the second device.

14. The second device of Claim 12, wherein the second device is further caused to: 30 receive, from the first device, a length of the sequence of bits and the number of hash functions for hashing the unique identification.

15. The second device of Claim 9, wherein the second device is further caused to: determine a duration since the transmission block is transmitted;

determine whether the duration exceeds a time threshold for an indication of the reception state; and

in response to a determination that the duration is below the time threshold, determine the reception state of the transmission block based on the sequence of bits.

5

16. The second device of Claim 9, wherein the first device comprises a network device and the second device comprises a terminal device.

17. A method, comprising:

10 determining reception states of a plurality of transmission blocks received from at least one second device;

generating a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks corresponds to one or more bits in the sequence; and

15 transmitting the sequence of bits to the at least one second device as indication of the reception states.

18. The method of Claim 17, wherein generating the sequence of bits comprises: assigning a first value to bits in the sequence; and

20 in response to a failure in receiving a first transmission block of the plurality of transmission blocks, assigning a second value to a first subset of bits in the sequence that are corresponding to the first transmission block, the second value being different from the first value.

25 19. The method of Claim 18, wherein the method further comprises:

in response to a failure in receiving a second transmission block of the plurality of transmission blocks, assigning the second value to a second subset of bits in the sequence that are corresponding to the second transmission block, the second subset of bits being at least partially different from the first subset of bits.

30

20. The method of Claim 18, wherein assigning the second value to the first subset of bits that are corresponding to the first transmission block comprises:

obtaining a unique identification of the first transmission block; and

determining positions of the first subset of bits in the sequence by hashing the

unique identification.

21. The method of Claim 20, wherein obtaining the unique identification of the first transmission block comprises determining the unique identification of the first transmission block based on at least one of:

an identification of a second device from which the first transmission block is received;

an identification of a Hybrid Automatic Repeat reQuest process during which the first transmission block is received; and

an identification of the first transmission block used to distinguish the first transmission block from other transmission blocks of the second device.

22. The method of Claim 20, wherein the method further comprises:

determining a failure rate of transmission blocks which have been received by the first device;

determining a tolerance of false rate for the indication of the reception states;

determining a length of the sequence of bits, based on the failure rate, the tolerance of false rate and the number of the plurality of transmission blocks; and

determining the number of hash functions for hashing the unique identification based on the tolerance of false rate.

23. The method of Claim 22, wherein the method further comprises:

transmitting the length of the sequence of bits and the number of hash functions to the at least one second device.

24. The method of Claim 17, wherein the first device comprises a network device and the at least one second device comprises a plurality of terminal devices.

25. A method, comprising:

transmitting a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device;

receiving at least one portion of a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and

determining a reception state of the transmission block based on the at least one

portion of the sequence of bits.

26. The method of Claim 25, wherein determining the reception state of the transmission block comprises:

5 determining a subset of bits in the at least one portion of the sequence that are corresponding to the transmission block;

determining whether the subset of bits comprises a bit of a first value; and

in response to absence of the bit of the first value, determining that a failure in receiving the transmission block by the first device occurs.

10

27. The method of Claim 26, wherein the method further comprises:

in response to a determination that the failure in receiving the transmission block by the first device occurs, retransmitting the transmission block to the first device.

15

28. The method of Claim 26, wherein determining a subset of bits in the sequence that are corresponding to the transmission block comprises:

obtaining a unique identification of the transmission block; and

determining positions of the subset of bits in the sequence by hashing the unique identification.

20

29. The method of Claim 28, wherein obtaining the unique identification of the transmission block comprises determining the unique identification of the transmission block based on at least one of:

an identification of the second device;

25

an identification of a Hybrid Automatic Repeat reQuest process during which the transmission block is transmitted; and

an identification of the transmission block used to distinguish the transmission block from other transmission blocks of the second device.

30

30. The method of Claim 28, wherein the method further comprises:

receiving, from the first device, a length of the sequence of bits and the number of hash functions for hashing the unique identification.

31. The method of Claim 25, wherein the method further comprises:

determining a duration since the transmission block is transmitted;

determining whether the duration exceeds a time threshold for an indication of the reception state; and

in response to a determination that the duration is below the time threshold,
5 determining the reception state of the transmission block based on the sequence of bits.

32. The method of Claim 25, wherein the first device comprises a network device and the second device comprises a terminal device.

10 33. An apparatus, comprising:

means for determining reception states of a plurality of transmission blocks received from at least one second device;

means for generating a sequence of bits based on the reception states of the plurality of transmission blocks such that each of the plurality of transmission blocks
15 corresponds to one or more bits in the sequence; and

means for transmitting the sequence of bits to the at least one second device as indication of the reception states.

34. An apparatus, comprising:

20 means for transmitting a transmission block to a first device, the first device receiving a plurality of transmission blocks at least from the second device;

means for receiving a sequence of bits from the first device, each of the plurality of transmission blocks corresponding to one or more bits in the sequence; and

25 means for determining a reception state of the transmission block based on the sequence of bits.

35. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method of any of claims 17-24.

30 36. A non-transitory computer readable medium comprising program instructions for causing an apparatus to perform at least the method of any of claims 25-32.

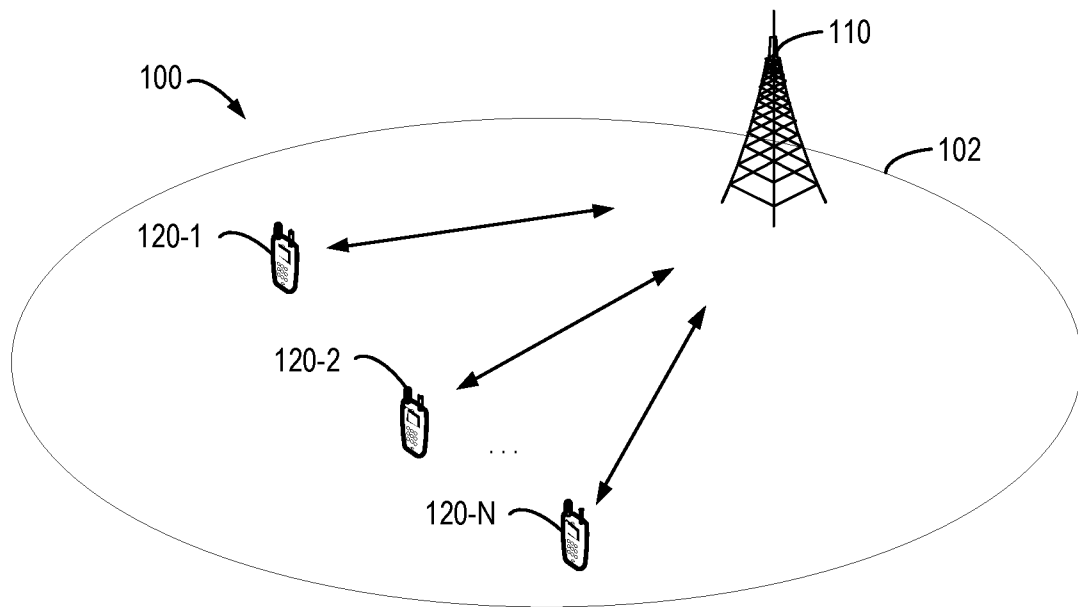


Fig. 1

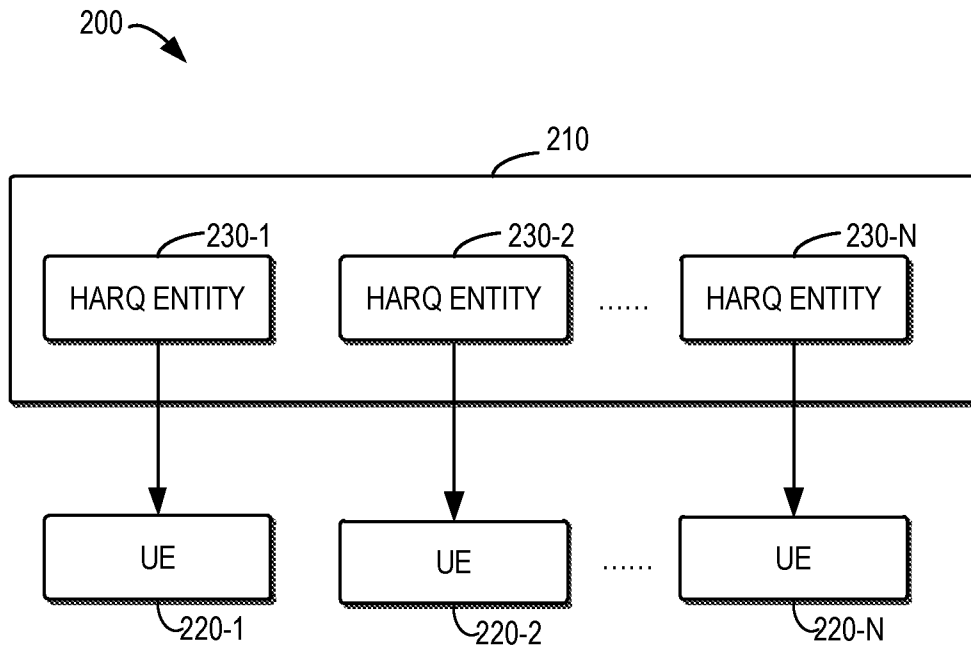


Fig. 2

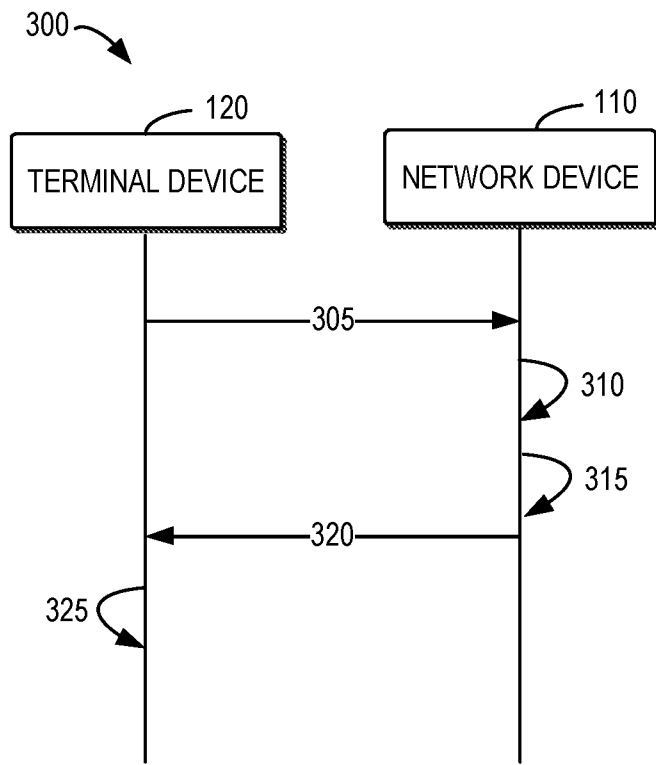


Fig. 3

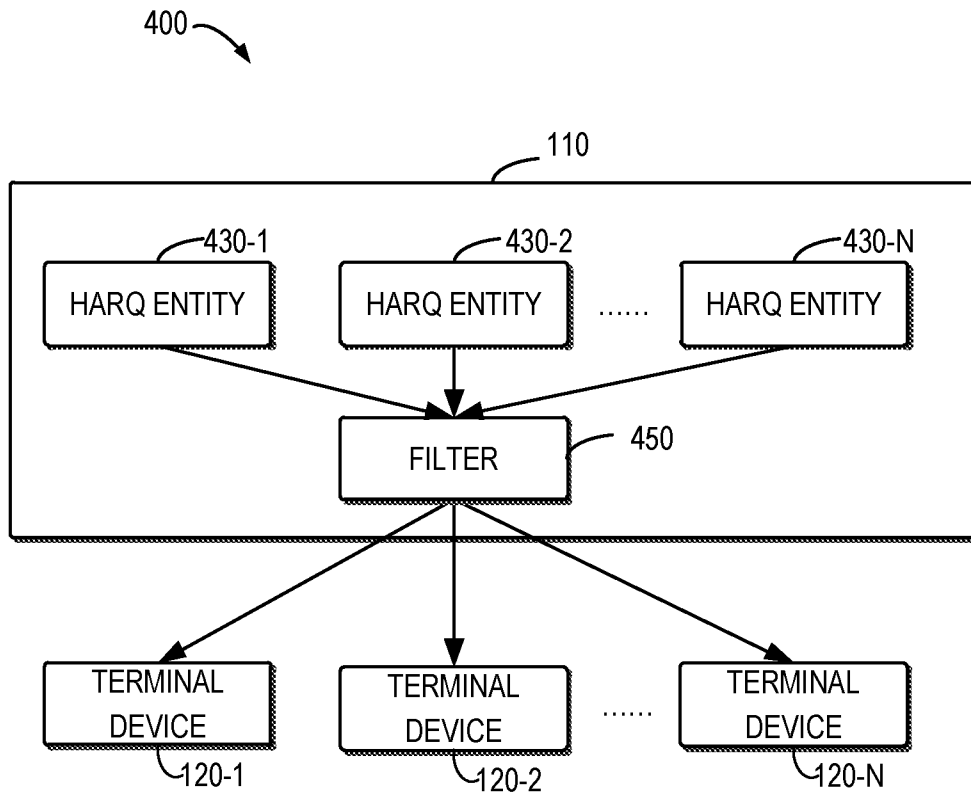


Fig. 4

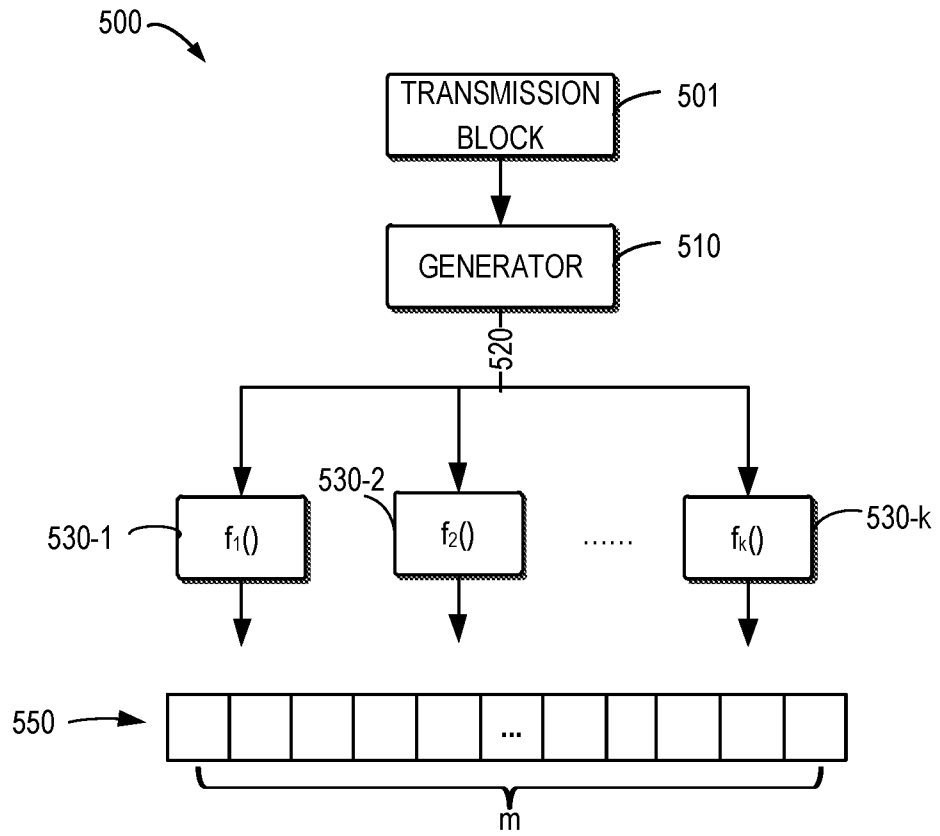


Fig. 5

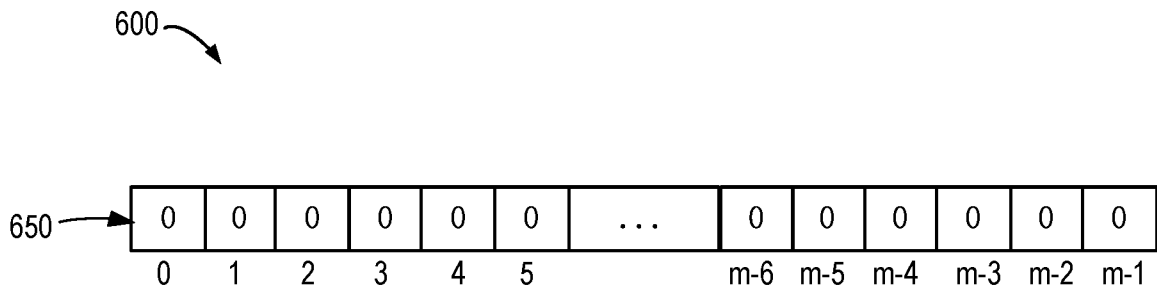


Fig. 6A

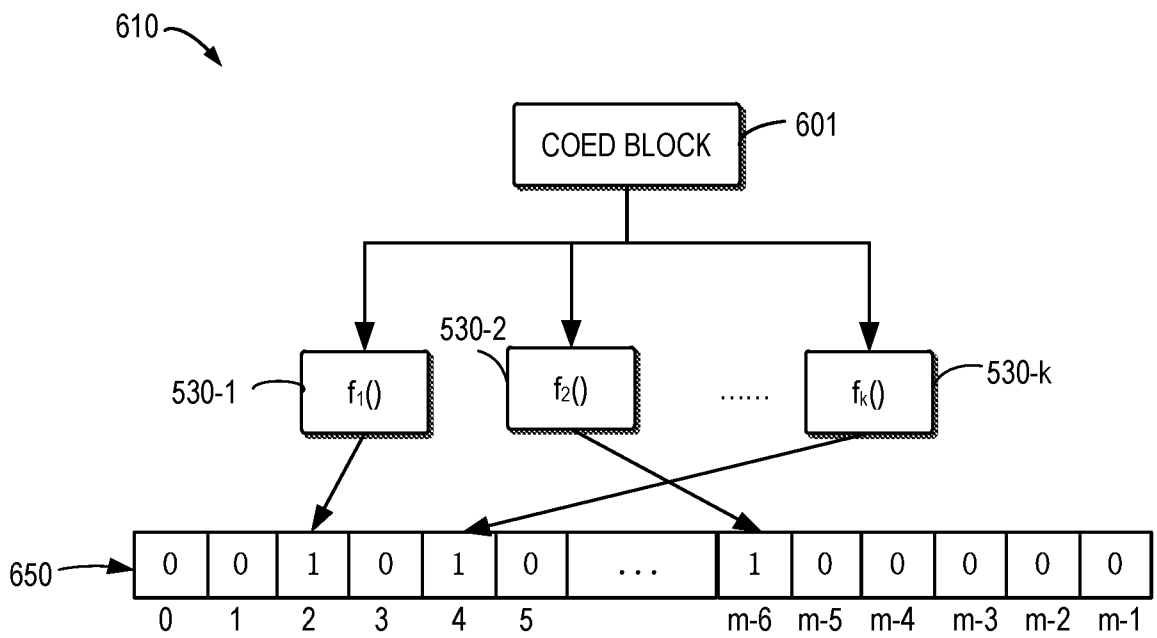


Fig. 6B

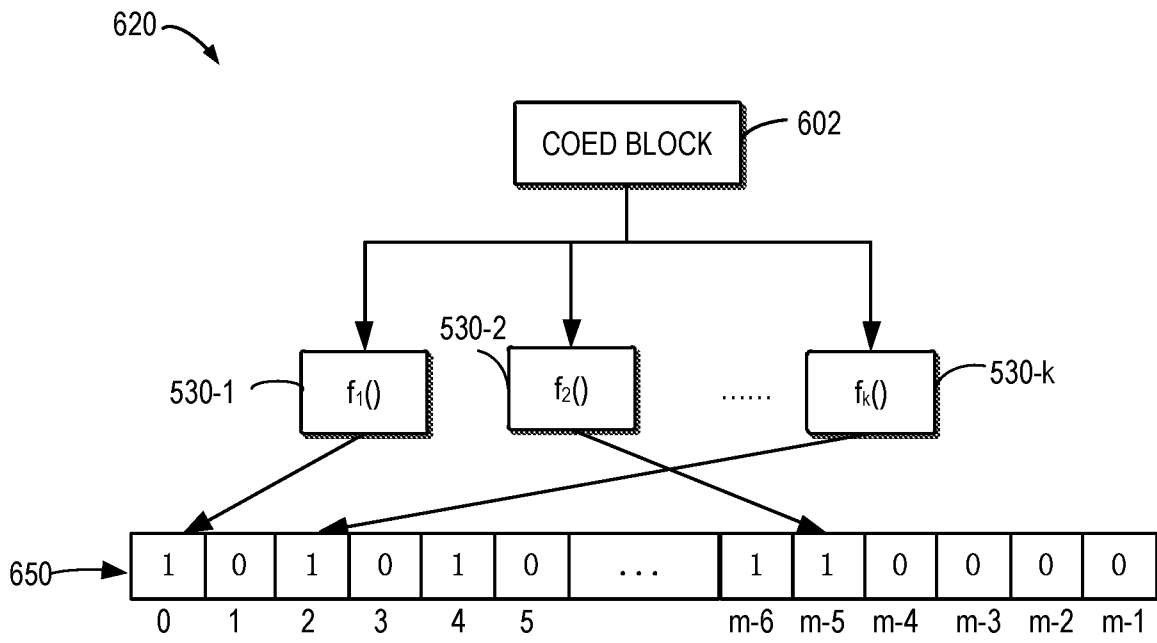


Fig. 6C

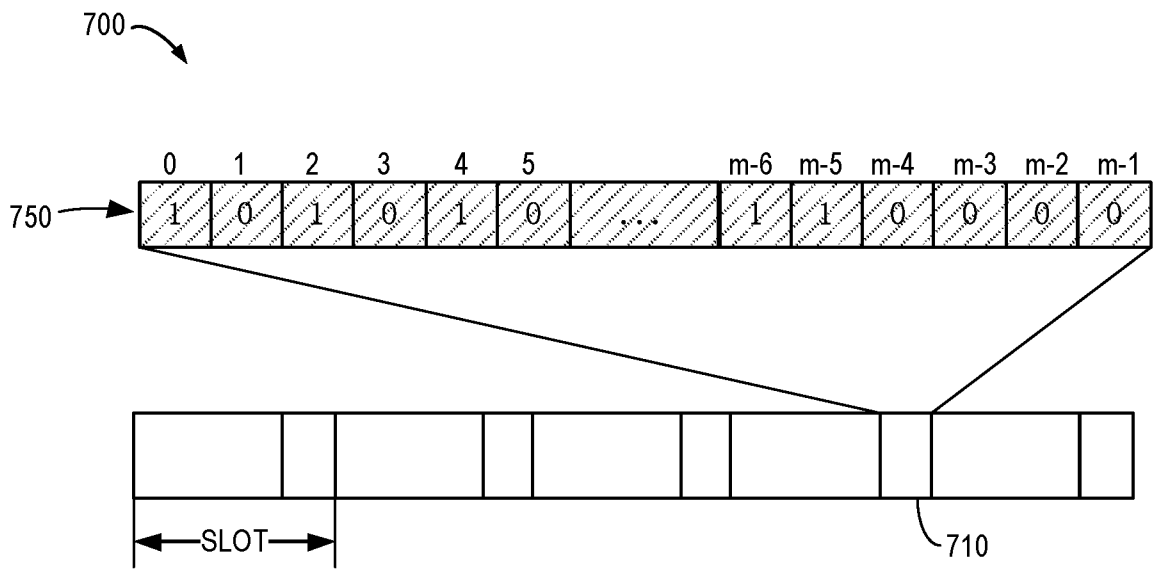


Fig. 7

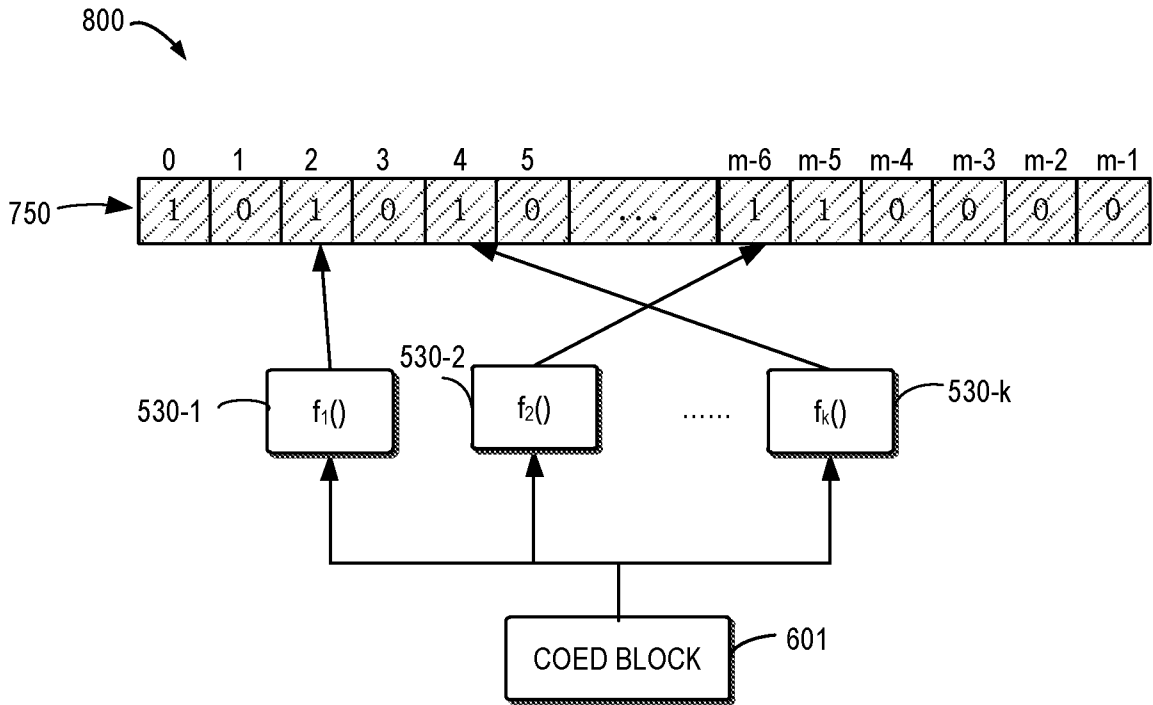


Fig. 8A

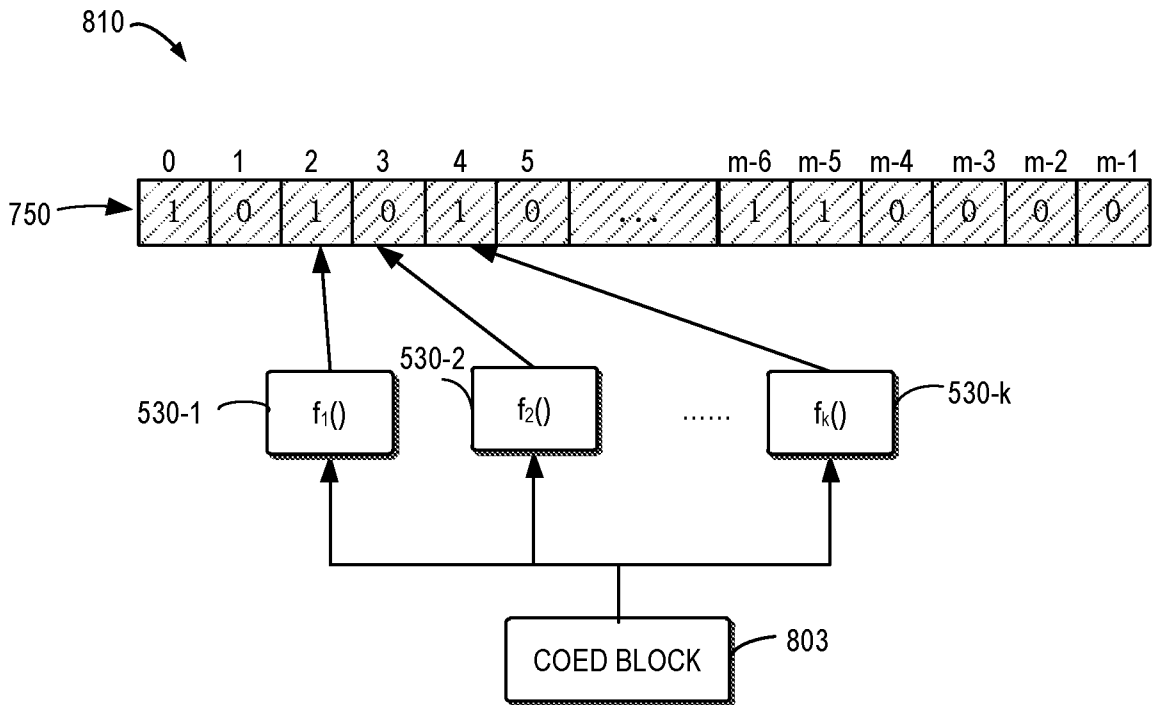


Fig. 8B

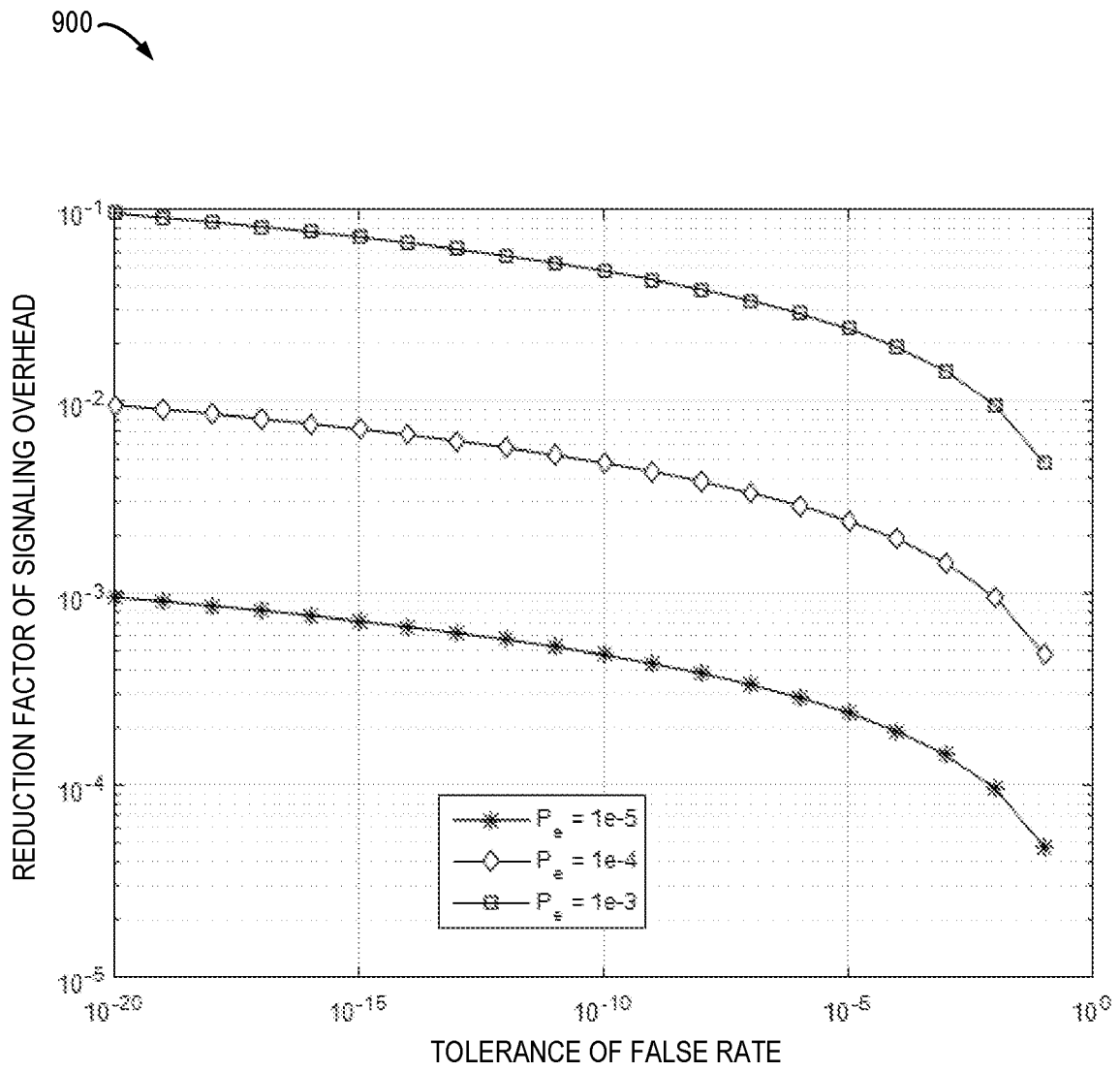
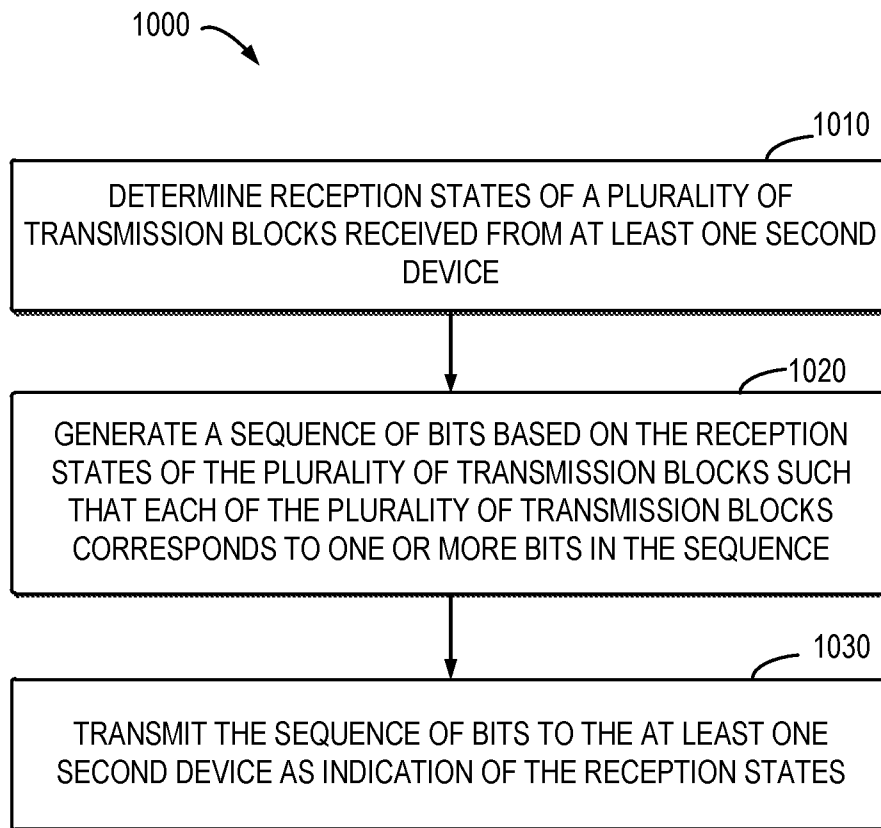


Fig. 9

**Fig. 10**

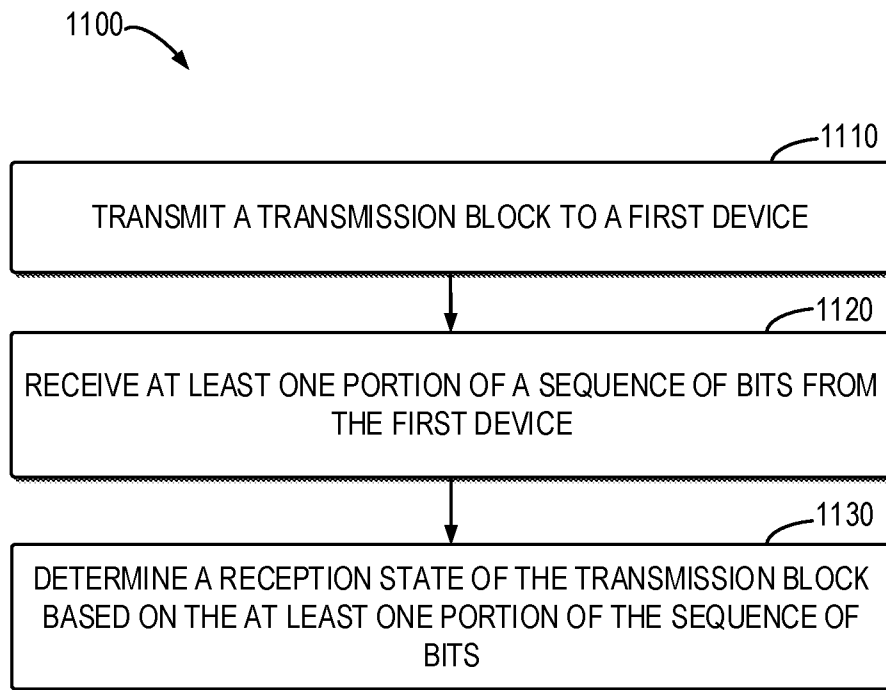


Fig. 11

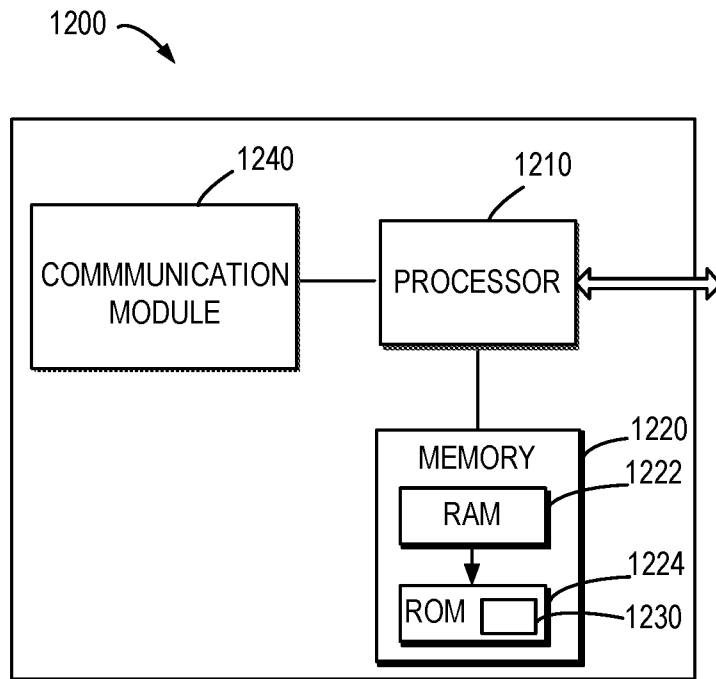


Fig. 12

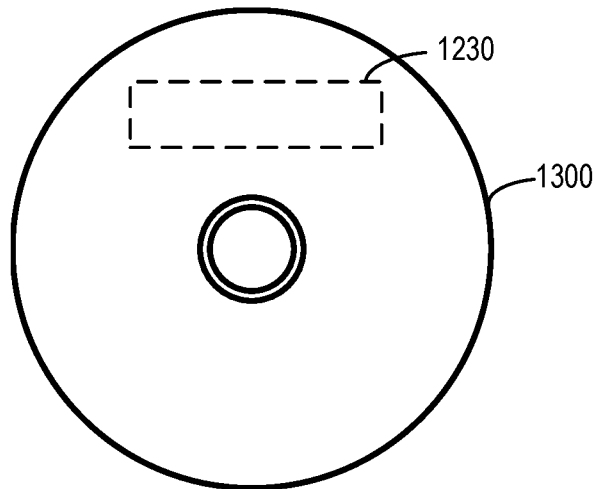


Fig. 13

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2019/096282

A. CLASSIFICATION OF SUBJECT MATTER		
H04L 1/16(2006.01)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)		
H04L, 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)		
WPI,EPODOC,CNPAT,CNKI,3GPP:HARQ, bit, sequence, NACK, failure, erroneous, error, mistake, state, acknowledgement, status, block, split, port+, hash, correspond+, map+		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2015137854 A1 (TELEFONAKTIEBOLAGET L M ERICSSONPUBL) 17 September 2015 (2015-09-17) claims 1-5, description, pages 10-12	1-36
A	US 2015110029 A1 (LG ELECTRONICS INC.) 23 April 2015 (2015-04-23) the whole document	1-36
A	EP 2224633 A1 (RESEARCH IN MOTION LIMITED) 01 September 2010 (2010-09-01) the whole document	1-36
A	US 2013094437 A1 (COLLABERA SOLUTIONS PRIVATE LIMITED) 18 April 2013 (2013-04-18) the whole document	1-36
A	EP 3327968 A1 (ZTE CORPORATION) 30 May 2018 (2018-05-30) the whole document	1-36
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
01 April 2020		16 April 2020
Name and mailing address of the ISA/CN		Authorized officer
National Intellectual Property Administration, PRC 6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088 China		JIA, Yu
Facsimile No. (86-10)62019451		Telephone No. 86-10-53961785

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2019/096282

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
WO	2015137854	A1	17 September 2015	None	
US	2015110029	A1	23 April 2015	WO	2013162247 A1 31 October 2013
EP	2224633	A1	01 September 2010	AT	533244 T 15 November 2011
				CA	2694933 A1 27 August 2010
US	2013094437	A1	18 April 2013	None	
EP	3327968	A1	30 May 2018	CN	106385309 A 08 February 2017
				US	2018227085 A1 09 August 2018
				WO	2017020679 A1 09 February 2017