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(54) Title: RETRANSMISSION OF POLAR CODE WITH REORDERED INFORMATION BITS

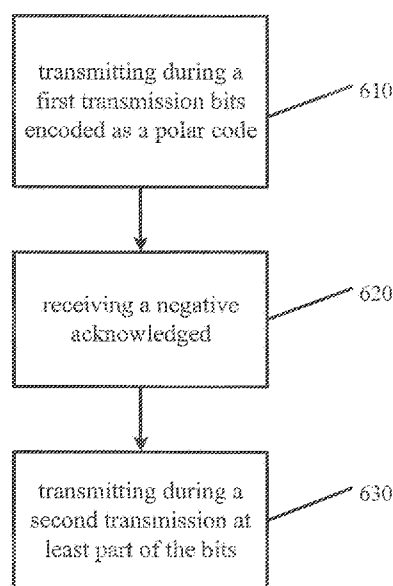


Figure 6

(57) Abstract: Various communication systems may benefit from improved performance. For example, communication systems may benefit an improved transmission in which the data bits are reordered to increase the reliability of the transmitted data bits. A method, in certain embodiments, may include transmitting during a first transmission a plurality of bits encoded as a polar code from a user equipment or a network entity to the network entity or the user equipment. The method may also include transmit during a second transmission at least part of the plurality of bits encoded as the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.



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RETRANSMISSION OF POLAR CODE WITH REORDERED INFORMATION BITS

BACKGROUND:

5 **Field:**

[0001] Various communication systems may benefit from improved performance. For example, communication systems may benefit an improved transmission in which the data bits are reordered to increase the reliability of the transmitted data bits.

10 **Description of the Related Art:**

[0002] In 3rd Generation Partnership Project (3GPP) 5th generation (5G) technology, ultra-reliability and low-latency communications (URLLC) between network entities utilize relatively short data bits. 5G technology also utilizes polar coding for control channel coding in an enhanced mobile broadband (eMBB) scenario. Polar codes are
15 high capacity achieving codes that use channel polarization along with low decoding complexity, and can be used in multiple access channels.

[0003] Polar codes help to provide for high reliability transmissions of blocks having short sizes, such as those used in URLLC. For short block size messages, retransmission of messages are used because a one-time transmission with fixed code
20 rate does not meet the high level performance requirements of 5G. In a 5G environment, retransmission is therefore needed to meet the high quality of service requirements.

[0004] 5G technology may also utilize hybrid automatic repeat request (HARQ) schemes. HARQ is a combination of automatic repeat request (ARQ) error control
25 and an error correction technique, such as soft combinations. ARQ is an error control method for data transmission that uses acknowledgments and timeouts to achieve reliable data transmission. In soft combinations, data packets that are not properly

received or decoded are not discarded. Rather the data packets are stored in a buffer, and combined with the next transmission. HARQ can be used along with polar coding to increase channel capacity in a 5G communication system.

5 SUMMARY:

[0005] A method, in certain embodiments, may include transmitting during a first transmission a plurality of bits encoded as part of a polar code from a user equipment or a network entity to the network entity or the user equipment. The method may also include transmitting during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0006] According to certain embodiments, an apparatus may include at least one memory including computer program code, and at least one processor. The at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to transmit during a first transmission a plurality of bits encoded as part of a polar code from a user equipment or a network entity to the network entity or the user equipment. The at least one memory and the computer program code may also be configured, with the at least one processor, at least to transmit during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0007] An apparatus, in certain embodiments, may include means for transmitting during a first transmission a plurality of bits encoded as part of a polar code from a

user equipment or a network entity to the network entity or the user equipment. The apparatus may also include means for transmitting during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the
5 encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0008] According to certain embodiments, a non-transitory computer-readable medium encoding instructions that, when executed in hardware, perform a process. The process may include transmitting during a first transmission a plurality of bits
10 encoded as part of a polar code from a user equipment or a network entity to the network entity or the user equipment. The process may also include transmitting during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an
15 order in which the plurality of bits were positioned during the first transmission.

[0009] According to certain embodiments, a computer program product encoding instructions for performing a process according to a method including transmitting during a first transmission a plurality of bits encoded as part of a polar code from a user equipment or a network entity to the network entity or the user equipment. The
20 method may also include transmitting during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0010] A method, in certain embodiments, may include receiving during an initial
25 transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity. The method may

also include receiving at the network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0011] According to certain embodiments, an apparatus may include at least one memory including computer program code, and at least one processor. The at least one memory and the computer program code may be configured, with the at least one processor, to cause the apparatus at least to receive during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity. The at least one memory and the computer program code may also be configured, with the at least one processor, at least to receive at the network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0012] An apparatus, in certain embodiments, may include means for receiving during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity. The apparatus may also include means for receiving at the network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

[0013] According to certain embodiments, a non-transitory computer-readable

medium encoding instructions that, when executed in hardware, perform a process. The process may include receiving during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity. The process may also include receiving at the
5 network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

10 **[0014]** According to certain embodiments, a computer program product encoding instructions for performing a process according to a method including receiving during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity. The method may also include receiving at the network entity or the user equipment
15 during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

20 **BRIEF DESCRIPTION OF THE DRAWINGS:**

[0015] For proper understanding of the invention, reference should be made to the accompanying drawings, wherein:

[0016] Figure 1 illustrates a bit diagram according to certain embodiments.

[0017] Figure 2 illustrates a bit diagram according to certain embodiments.

25 **[0018]** Figure 3 illustrates a bit diagram according to certain embodiments.

[0019] Figure 4 illustrates a bit diagram according to certain embodiments.

[0020] Figure 5 illustrates a flow diagram according to certain embodiments.

[0021] Figure 6 illustrates a flow diagram according to certain embodiments.

[0022] Figure 7 illustrates a system according to certain embodiments.

[0023] Figure 8 illustrates a system according to certain embodiments.

5 DETAILED DESCRIPTION:

[0024] In some embodiments, a data bit reordered and /or a log-likelihood ratio (LLR) combination may be used to improve the retransmission of data bits in a 5G URLLC environment. Retransmission may include either repetition of data bits or transmitting data bits during a subsequent time period. A first transmission, as described below, may be an initial or original transmission, while a second transmission may be a retransmission. Certain embodiments may involve the use of an incremental freezing HARQ (IF-HARQ). IF-HARQ may be a powerful HARQ design for polar codes in 5G channel coding for short block sizes. A block may include one or more data bits. In IF-HARQ, only a part or a portion of the bits transmitted originally is retransmitted. The code rate may reduce in each retransmission, meaning that each retransmission may include fewer bits, Once the bits in the second transmission are decoded correctly, the correct decoded bits will become frozen or hard, which can be used for the decoding of a first transmission. With each retransmission, code rates decrease and performance increases.

[0025] In certain embodiments, IF-HARQ may be extended to Incremental Redundancy HARQ (IR-HARQ) or Chase Combining HARQ (CC-HARQ). This may help to achieve a greater capacity gain, in certain embodiments. In some embodiments, IF-HARQ and IR-HARQ may utilize hard or frozen bits. Hard or frozen bits are both bits that have been decoded. When the decoded hard bits in the retransmission contain an error, however, the decoded hard bits may not be used to properly decode the whole information packet

[0026] Such an error, for example, may occur since channel conditions may be

different, and at times fluctuate in a rapid manner. The network entity may therefore decode a data bit with an error or the error checking of a given data bit may fail. In other embodiments, when the block length of is short, good channel polarization may not be supported, which can result in bad decoding. In other words, the hard bits may
5 contain errors in fast fading channels, even when the coding rate may be low.

[0027] In IF-HARQ or IR-HARQ, which utilize hard bits combination, the retransmitted bits can be used as frozen bits in decoding previous transmissions. In such retransmissions, the same bit order as is used in the first transmission is also used in the retransmission. This may result in lower reliability data bits always remaining in
10 lower reliability positions in both the initial transmission and any subsequent transmissions. This may result in a higher bit error rate for the lower reliability data bits mention above and results in error for retransmission, the performance of the communication system may suffer. Similarly, in CC-HARQ data bits in bad channels may always be transmitted in bad channels, and performance of the communication
15 system may suffer.

[0028] In certain embodiments, therefore, the position of the data bits in the retransmission may be sorted differently. Sorted differently may mean that the position of the data bits may are reordered, switched, and/or adjusted, so that at least part or some of the plurality of bits are in a different order than the initial transmission.
20 For example, in some embodiments the bit positions in the retransmission may be transmitted in an inverse of the order in which the bits were transmitted in the initial or original transmission. In other embodiments, the order of the bit during polar encoding in the retransmission may be the order in which the bits of the original transmission were decoded by the network, or an inverse of the order in which the bits of the
25 original transmission were decoded by the network. The bits transmitted during the first transmission and the second transmission may partially or fully overlap or may be different. For example, in IF-HARQ and IR-HARQ, the encoded bits are different for

the second and first transmission. For CC-HARQ, although the source bits may be the same for first and second transmission, the encoded bits may be different for the first and second transmission because of the new order of the data bits before encoding. The above sorting of the bits may be compatible with combining and/or replacing LLRs of one or more data bits.

[0029] Figure 1 illustrates a bit diagram according to certain embodiments. In particular, Figure 1 illustrates a first or an initial transmission 110, and three subsequent secondary transmissions or retransmissions 120, 130, and 140 in an IF-HARQ. During the first transmission 110, the user equipment or the network entity may transmit a block including 16 data bits u_k to the network entity or the user equipment, where k represents the bit index. The network entity, for example, may be a base station, such as a 5G NodeB (5G NB). As can be seen in Figure 1, u_{13} , u_{14} , u_{15} , and/or u_{16} have been previously frozen, and as such have been shaded in for illustrative purposes. In certain embodiments, the remaining bits in the block that have not yet been frozen may have been flagged during a cyclic redundancy check (CRC) by the network entity. When a data bit is flagged during the CRC, an error may have occurred in the decoding of that data bit.

[0030] Some embodiments of second transmissions or the retransmissions 120, 130, and/or 140 may involve sorting the data bits in a position that may be different from the position of the data bits transmitted during the first transmission. For example, second transmission or retransmission 120, which may be the first time at least part of the plurality of bits are retransmitted after the initial or first transmission, may include inverting the order of the plurality of bits that were initially transmitted. In certain embodiments, the data bits may be sorted differently or reordered in every secondary transmission. The sorting of the data bits may be done in order to reset the bit in the lowest reliability position of the previous transmission into the highest reliable position of the new retransmission. For example, as can be seen in initial

transmission 110, bit u_{12} is located in the most unreliable position in the block. In retransmission 120, on the other hand, data bit u_{12} is placed in the most reliable position in the block.

[0031] In other words, during retransmission the positions of the data bits are sorted
 5 based on the reliability of the initial transmission 110, or any other previous transmission, in an increasing order. For example, reliability of three data bits in an initial transmission may be Z_i , Z_j , and Z_k , where i , j , and k represent the index of the bits. If during the initial transmission the order of transmission is Z_i , Z_j , and Z_k , then the order of the bits during retransmission may be u_k , u_j , and u_i . The order the bits may
 10 therefore be inversed between the initial transmission 110 and the retransmission 120.

[0032] As can be seen in Figure 1, during the first retransmission 120, half of the plurality of bits that were initially transmitted in 110, and which were located in the worst reliability position during initial transmission 110, are retransmitted. The
 15 inversing or reordered of the order of the plurality of bits moves u_{12} , which had the worst position in the initial transmission, into the most reliable position in the block. u_{11} , which had the second worst position in the initial transmission, may be moved or switching into the second most reliable position in the block. The remaining bits, u_{10} , u_9 , u_8 , u_7 , may be sorted in a similar manner.

[0033] Figure 1 illustrates an initial transmission 110, a first retransmission 120, a
 20 second retransmission 130, and a third retransmission or repetition 140. In second retransmission 130 and third retransmission 140, rather than inversed the order of the previous transmission, the user equipment or the network entity may reorder the positions of the data bits in the order in which the retransmitted plurality of bits were decoded after the initial transmission of the data bits, or in an inverse of the order in
 25 which the retransmitted plurality of bits were decoded after the initial transmission of the data bits. In polar codes, the successive cancellation (SC) decoding order or any other form of decoding, such as successive cancellation list (SCL) and

CRC-aided SCL (CASCL) are sequential, and as such both the user equipment and base station know the decoding order. Using decoding order or inverse decoding order of the initial transmission, may help to increase reliability of the plurality bits. The earlier decoded the bit, the higher reliability increase.

5 [0034] In certain example embodiments, when the first bit input to the encoder is a frozen bit, the inverse of decoding order may be used to reorder retransmitted bits in retransmissions. When the last bit input to the encoder is a frozen bit, the decoding order may be used to reorder retransmitted bits in retransmissions.

[0035] For example, in second retransmission 130, data bits u_5 , u_6 , u_7 , and u_8 are
 10 transmitted. In first or initial transmission 110, u_5 was the eighth data bit decoded by the network, u_6 was the thirteenth data bit decoded by the network, u_7 was the eleventh data bit decoded by the network, and u_8 was the tenth data bit decoded by the network. In second retransmission 130, the data bits may therefore be positioned as the initial decoding order. In other words, the second retransmission 130 may position the data
 15 bits as follows: u_5 , u_8 , u_7 , and u_6 .

[0036] In certain other embodiments, the second retransmission or repetition 130 may also simply be the inverse order of the transmission of either first retransmission 120 or transmission 110. Third retransmission 140 may also be ordered similar to second retransmission 130, according to the decoding order after the initial transmission. In
 20 other embodiments, third retransmission 140 may be reordered according to any other method, which may be either the same or different than second retransmission 130.

[0037] In certain embodiments, at least one same data bit may exist in both the first transmission and the second transmission. For example, as can be seen in Figure 1, u_7 and u_8 both exist in the first transmission 110 and second transmission 120. In such
 25 embodiments, it may be possible to jointly measure the reliability of u_7 and u_8 . Measuring reliability of bits jointly, as a bit group, may be done when the worst reliability bits, or group of bits, in the first and second are sorted into a best reliability

position. In other words, the worst joint reliability position in one or more previous transmissions and/or re-transmissions may be placed in the best joint reliability position in a subsequent retransmission.

[0038] Certain embodiments may use a one bit granularity reorder, which means that the bits reliability or decoding sequence is measured for each bit. In other embodiments, however, the bits reliability or decoding sequence for blocks that contain multiple bits may be measured. In such an embodiment, the bits are divided into groups, and the reliability and decoding sequence for the group as a whole may be assessed. Assessing the reliability of the group is known as joint reliability.

[0039] For example, as can be seen in Figure 1, bit group u_7 and u_8 in first retransmission 120 and u_5 and u_6 in initial transmission 110 may be deemed the group of bits having the worst reliability of the previous transmissions. As such the group, as a whole, may be put in the best reliability position of the subsequent transmission. In addition, the order of the bits in the subsequent transmission may be placed in the order of the decoding of the initial transmission or in an inverse of the order of the decoding of the initial transmission.

[0040] Retransmissions may occur when errors are detected in previous transmissions during, for example, a CRC check at the network. The LLRs from previous transmissions may be regarded as interfering by probability. Interfering by probability may mean that the LLR information from previous transmission may be regarded as interference to the current transmission when at least part of the previously transmitted bits and the current transmitting bits are combined. Since retransmitting may occur when the previous decoding failed, there is a probability that there is an error in the previous LLR information. Reliability of a transmission may be evaluated based on SC decoding used in the decoding of polar codes, in which the bits that are decoded first are deemed to be in a more reliable position. SC decoding algorithm may decode each bit sequentially from the first one bit to the last one bit. There may be an SC

decoding gain associated with positioning the bits in the order in which the bits were decoded or in an inverse of the order in which the bits were decoded. For example, the decoding order of u_5 , u_8 , u_7 , and u_6 is 8, 10, 11, and 13, and the order of the plurality of bits is as the decoding order of the initial transmission. This means that the order of retransmission may be u_5 , u_8 , u_7 , and u_6 .

[0041] Figure 2 illustrates a bit diagram according to certain embodiments. Certain embodiments may include a combining or replacing step when the decoding error check, such as CRC check, fails for all or some of the retransmissions. The combining step may include combining the LLR information of all decoded bits of all transmissions and/or retransmissions into the first decoding structure. LLR may be a likelihood ratio test used for comparing goodness of fit of an initial transmission of a plurality of data bits, and a subsequent retransmission of at least some of the plurality of data bits. The crosses in Figure 2 illustrate the combining process of the LLR information. Combining of the LLR information may occur when CRC check has failed, at which point some or all of the LLR information may be added. Combining the LLR may have several advantage. For example, the LLR combining step may prevent or delay the decoding failed event from occurring by decoding again some of the data bits included in subsequent retransmission.

[0042] In addition, the LLR combining process may make the LLR information more accurate. Since the bits in bad or poor reliability positions in the first transmission may be placed into a good or better reliability position in the second transmission, a more accurate result may be achieved from combining the LLRs. For the rest of retransmissions, the bits which are decoded may be placed in the front of the block, which may be deemed in a good position. This placement may allow for the obtaining of accurate LLR for the bits after the LLR combining. The bits decoded in the front of the block being more reliable may also bring decoding gains in the sequential decoding algorithm.

[0043] As shown in Figure 2, bits of first retransmission or replacement 240, the second retransmission or replacement 230, and/or third retransmission or replacement 220 are decoded. Once all retransmission CRC checks fail, a decoding failed event may not occur immediately, in certain embodiments. The decoding event may be that all four transmissions, including the initial transmission and the subsequent retransmissions, have failed. Rather, the LLR information of the failed retransmissions may be combined, and then again decoded by the network entity. The combined LLR information can improve the performance of the first decoding structure. If the combined first decoding structure fails, a failed decoding event may occur.

[0044] For example, if all transmissions failed, then the LLR information of data bits in the first retransmission or replacement 240, the second retransmission or replacement 230, and/or third retransmission or replacement 220 may be combined into first decoding structure 210. Then first decoding structure 210 may be decoded based on the combined LLRs of the data bits. In certain embodiments in which the LLRs from the previous transmission may be wrong, it may be possible to regard such a previous transmission as interference, and to discard the LLRs. The UE may then simply use the combined LLRs information of the retransmission, rather than the initial transmission.

[0045] Figure 3 illustrates a data bit diagram according to certain embodiments. In particular, Figure 3 illustrates certain embodiments that utilize IR-HARQ, in which at least some of the plurality of bits that are initially transmitted are repeated. Figure 3 illustrates two transmissions, an initial or first transmission 310 and a second transmission 320, which may be at least a partial retransmission of the initial transmission. In initial or first transmission 310, sub-channel set 311, which may include one or more data bits, may not be successfully decoded. This failure to properly decode sub-channel set 311 may be due to the reliability position of the

sub-channel set 311, or the data bits therein, within the channel used for transmission 310. Sub-channel set 311 may then be retransmitted in a second transmission 310 in a more reliable position 321. In certain embodiments, during the retransmitting the user equipment may inverse the order in which the plurality of bits or the sub-channels were initially transmitted. In other embodiments, the retransmitting may involve the decoding order of the initial or first transmission as the order of information bits input into polar encoding or an inverse of the decoding order of the initial or first transmission as the order of information bits input into polar encoding.

[0046] Certain embodiments may utilize CC-HARQ. In such embodiments, it may be possible to implement the bit reordering shown in Figure 1. Figure 4 illustrates a data bit diagram according to certain embodiments. In Figure 4, a combination of information sub-channel sets, which may include one or more data bits, are sorted differently or reordered from first transmission 410 to second transmission 420. The bits may be reordered similar to Figure 1. In second transmission 420, therefore, the information sub-channel set may be retransmitted in an inverse of the order in which the plurality of bits were initially transmitted in initial transmission 410. In some other embodiments, the information sub-channel set may be repeated in the decoding order or in the inverse decoding order of the plurality of bits.

[0047] Figure 5 illustrates a flow diagram according to certain embodiments. In particular, Figure 5 illustrates that the transmissions or retransmissions shown in Figures 1, 2, 3, and 4. In 510, a user equipment or a network entity may transmit a plurality of data bits to the network entity, such as a base station, or the user equipment, respectively. The transmission may be based on IF-HARQ, IR-HARQ, and/or CC-HARQ. In addition, the transmission may utilize constructed polar codes. Once the network entity or the user equipment receives the transmission, it may begin to decode the plurality of data bits, as shown in 511. An error check 512, such as a CRC check, may then be performed by the network entity or the user equipment. Other

embodiments may involve any other type of error check. If the received data bits pass the CRC check, then the network entity or the user equipment may determine whether all of the bits were properly decoded, as shown in 513. If so, the decoding may be deemed a success. If not, however, those bits who were properly decoded may be
5 frozen, as shown in step 514, while the remaining data bits are retransmitted, as shown in Figure 1.

[0048] If the CRC check in 512 failed, then the network entity or the user equipment may then check whether four retransmissions have occurred. Although Figure 5 describes checking whether four retransmissions have occurred, any other number of
10 retransmissions may be checked in 515. The network entity or the user equipment can then in 516 determine whether to initialize LLR combining, as shown in Figure 2. If combining LLRs has yet to be initialized, then LLR combining may occur in 517, and the combined LLRs may be decoded, as in 511. If a given number of retransmissions has not been achieved in 515, then the network entity or the user equipment may store
15 the decoded LLRs of the data bits.

[0049] In 519, the user equipment may decide whether to retransmit at least a part of the plurality of data bits, and sort the data bits in a different position from which the plurality of bits were first or initially transmitted. In other embodiments, the data bits may be sorted in an order in which the plurality of bits were decoded after the first
20 transmission, or in an inverse of the order in which the plurality of bits were decoded after the first transmission, or in an inverse of the order based on the reliability of the original transmission positions. In 520, the user equipment or the network entity may apply a sorting process, and in 530 the user equipment or the network entity may input the at least part of the plurality of bits into a polar encoder as an information bit.

[0050] Figure 6 illustrates a flow diagram according to certain embodiments. In particular, Figure 6 illustrates an embodiment of a user equipment or a network entity.
25 In step 610, the user equipment or network entity may transmit during a first

transmission a plurality of bits encoded as a polar code from a user equipment or a network entity to the network entity or the user equipment, respectively. The plurality of bit may be an input of the polar code. The network entity or the user equipment may then decode the received data bits. In step 620, the user equipment or the network entity may receive a negative acknowledgement. The negative acknowledgement may precede the second transmission of the at least part of the plurality of bits.

- [0051]** In step 630, the user equipment or the network entity may transmit during a second transmission at least part of the plurality of bits encoded as the polar code.
- 10 The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than the order in which the plurality of bits were positioned during the first transmission, as shown in Figures 1 and 3. In other words, the order or position in a later transmission may be different than, or an inverse of, the order used in an earlier transmission. The position may be a position
- 15 in which a bit is transmitted, decoded, or encoded. Positioning of the plurality of the bits in a different order may be at least in part dependent on the reliability of the position in which the bit is encoded and/or the decoding order of the bit in a previous transmission. The different order described below may be applied before encoding of the polar code.
- 20 **[0052]** For example, in some embodiments at least part of the plurality of bits may be sorted in accordance with the decoding order of the first transmission or in an inverse decoding order. In other embodiments, the bits may be sorted before the encoding of the second transmission according to an inverse of the order in which the plurality of bits are transmitted in the first transmission, and/or the order in
- 25 which the plurality of bits after the first transmission are decoded. The at least part of the plurality of bits are sorted by granularity of bit or bit group for the second transmission before encoding.

[0053] Figure 7 illustrates a flow diagram according to certain embodiments. In particular Figure 7 illustrates an embodiment of a network entity, such as a base station. In step 710, the network entity may receive during a first transmission a plurality of bits encoded as a polar code at a network entity from a user equipment.

5 The network entity may decode at least one of the plurality of bits, and store the decoded at least one plurality of bits at the base station. The network entity may then receive during a second transmission at least part of the plurality of bits encoded as the polar code, as shown in step 720. The at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than the
10 order in which the plurality of bits were positioned during the first transmission. The position may be a position in which a bit is transmitted or decoded within a block. In other words, the order or position in a later transmission may be different than, or an inverse of, the order used in an earlier transmission.

[0054] The different order before the encoding of the second transmission
15 comprises at least one of an inverse of the order in which the plurality of bits are encoded in the first transmission and/or the order in which the plurality of bits after the first transmission are decoded, and/or the inverse of the order in which the plurality of bits after the first transmission are decoded. The different order may also comprise the inverse order of the at least part of the plurality of bits before
20 encoding for a transmission between the first transmission and the second transmission. The different order may be signaled to the user equipment or the network entity.

[0055] In certain embodiments, as shown in Figure 2, the network entity may combine a log-likelihood ratio of the at least a part of the plurality bits decoded during the
25 first and second transmission, as shown in step 730. The log-likelihood ratio may be combined when a decoding error check has failed. In certain embodiments, the reordering can be performed before inputting into the polar encoding or before the

bits are mapped to positions with different reliability.

[0056] Figure 8 illustrates a system according to certain embodiments. It should be understood that each signal or block in Figures 1-7 may be implemented by various means or their combinations, such as hardware, software, firmware, one or more processors and/or circuitry. In one embodiment, a system may include several devices, such as, for example, network entity 820 or UE 810. The system may include more than one UE 810 and more one base station 820, although only one access node shown for the purposes of illustration. The network entity may be a base station, network node, an access node, a 5G NB or 5G BTS, a server, a host, or any of the other access or network node discussed herein.

[0057] Each of these devices may include at least one processor or control unit or module, respectively indicated as 811 and 821. At least one memory may be provided in each device, and indicated as 812 and 822, respectively. The memory may include computer program instructions or computer code contained therein. One or more transceiver 813 and 823 may be provided, and each device may also include an antenna, respectively illustrated as 814 and 824. Although only one antenna each is shown, many antennas and multiple antenna elements may be provided to each of the devices. Other configurations of these devices, for example, may be provided. For example, network entity 820 and UE 810 may be additionally configured for wired communication, in addition to wireless communication, and in such a case antennas 814 and 824 may illustrate any form of communication hardware, without being limited to merely an antenna.

[0058] Transceivers 813 and 823 may each, independently, be a transmitter, a receiver, or both a transmitter and a receiver, or a unit or device that may be configured both for transmission and reception. The transmitter and/or receiver (as far as radio parts are concerned) may also be implemented as a remote radio head which is not located in the device itself, but in a mast, for example. The operations

and functionalities may be performed in different entities, such as nodes, hosts or servers, in a flexible manner. In other words, division of labor may vary case by case. One possible use is to make a network node deliver local content. One or more functionalities may also be implemented as virtual application(s) in software that
5 can run on a server.

[0059] A user device or user equipment 810 may be a mobile station (MS) such as a mobile phone or smart phone or multimedia device, a computer, such as a tablet, provided with wireless communication capabilities, personal data or digital assistant (PDA) provided with wireless communication capabilities, portable media
10 player, digital camera, pocket video camera, navigation unit provided with wireless communication capabilities or any combinations thereof. In other embodiments, the user equipment may be replaced with a machine communication device that does not require any human interaction, such as a sensor, meter, or robot.

[0060] In some embodiments, an apparatus, such as a network entity, may include
15 means for carrying out embodiments described above in relation to Figures 1-7. In certain embodiments, at least one memory including computer program code can be configured to, with the at least one processor, cause the apparatus at least to perform any of the processes described herein.

[0061] Processors 811 and 821 may be embodied by any computational or data
20 processing device, such as a central processing unit (CPU), digital signal processor (DSP), application specific integrated circuit (ASIC), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), digitally enhanced circuits, or comparable device or a combination thereof. The processors may be implemented as a single controller, or a plurality of controllers or processors.

[0062] For firmware or software, the implementation may include modules or unit
25 of at least one chip set (for example, procedures, functions, and so on). Memories 812 and 822 may independently be any suitable storage device, such as a

non-transitory computer-readable medium. A hard disk drive (HDD), random access memory (RAM), flash memory, or other suitable memory may be used. The memories may be combined on a single integrated circuit as the processor, or may be separate therefrom. Furthermore, the computer program instructions may be stored in the memory and which may be processed by the processors can be any suitable form of computer program code, for example, a compiled or interpreted computer program written in any suitable programming language. The memory or data storage entity is typically internal but may also be external or a combination thereof, such as in the case when additional memory capacity is obtained from a service provider. The memory may be fixed or removable.

[0063] The memory and the computer program instructions may be configured, with the processor for the particular device, to cause a hardware apparatus such as network entity 820 or UE 810, to perform any of the processes described above (see, for example, Figures 1-7). Therefore, in certain embodiments, a non-transitory computer-readable medium may be encoded with computer instructions or one or more computer program (such as added or updated software routine, applet or macro) that, when executed in hardware, may perform a process such as one of the processes described herein. Computer programs may be coded by a programming language, which may be a high-level programming language, such as objective-C, C, C++, C#, Java, etc., or a low-level programming language, such as a machine language, or assembler. Alternatively, certain embodiments may be performed entirely in hardware.

[0064] Furthermore, although Figure 8 illustrates a system including a network entity 820 and UE 810, certain embodiments may be applicable to other configurations, and configurations involving additional elements, as illustrated and discussed herein. For example, multiple user equipment devices and multiple network entities may be present, or other nodes providing similar functionality,

such as nodes that combine the functionality of a user equipment and a network entity, such as a relay node. The UE 810 may likewise be provided with a variety of configurations for communication other than communication network entity 820. For example, the UE 810 may be configured for device-to-device or machine-to-machine communication.

[0065] The above embodiments provide for improvements to the functioning of a network and/or to the functioning of the network entities within the network, or the user equipment communicating with the network. Specifically, certain embodiments allow for reordering data bits so that the bits in the lower reliability position are placed in the highest reliability position in the retransmission. The LLR information of the data bits may therefore become more accurate and reliable, which can allow for a correct LLR combining or replacement. The LLR information combining process may allow for the bits in low reliability positions of the initial transmissions to be correct after being combined with more accurate information from subsequent retransmissions. This can improve the resource utilization of the network, and decrease the need to retransmit error prone messages in a 5G URLLC environment.

[0066] The features, structures, or characteristics of certain embodiments described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases “certain embodiments,” “some embodiments,” “other embodiments,” or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearance of the phrases “in certain embodiments,” “in some embodiments,” “in other embodiments,” or other similar language, throughout this specification does not necessarily refer to the same group of embodiments, and the described features, structures, or characteristics may be

combined in any suitable manner in one or more embodiments.

[0067] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. While some embodiments may be directed to a 5G environment, other embodiments can be directed to other 3GPP technology, such as Long Term Evolution (LTE), LTE Advanced, 4th generation (4G), or Internet of Things technology.

[0068] Partial Glossary

[0069]	3GPP	3rd Generation Partnership Project
[0070]	5G	5th generation
[0071]	CRC	Cyclic Redundancy Check
[0072]	LLRs	Log-Likelihood Ratios
[0073]	IF-HARQ	Incremental Freezing Hybrid Automatic Repeat Request
[0074]	IR-HARQ	Incremental Redundancy Hybrid Automatic Repeat Request
[0075]	CC-HARQ	Chance Combining Hybrid Automatic Repeat Request
[0076]	SC	Successful Cancellation
[0077]	UE	User Equipment
[0078]	BS	Base Station
[0079]	5G BTS	5G base station

WHAT IS CLAIMED IS:

1. An apparatus comprising:

at least one processor; and

at least one memory including computer program code,

5 wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:

transmit during a first transmission a plurality of bits encoded as part of a polar code from a user equipment or a network entity to the network entity or the user equipment; and

10 transmit during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code, wherein the at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

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2. The apparatus according to claim 1, wherein the different order before the second transmission comprises at least one of an inverse of the order in which the plurality of bits are encoded in the first transmission, or the order in which the plurality of bits after the first transmission are decoded, or the inverse of the order in

20 which the plurality of bits are decoded after first transmission.

3. The apparatus according to claim 1, wherein the at least part of the plurality of bits are sorted by granularity of bit or bit group for the second transmission before encoding.

5 4. The apparatus according to claim 1, wherein a log-likelihood ratio of the at least a part of the plurality of bits decoded are combined from the first transmission and the second transmission.

10 5. The apparatus according to claim 1, wherein the plurality of bits in the initial transmission that are in a low reliability position range are inversed to be in a high reliability position range during the second transmission.

15 6. The apparatus according to claim 1, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:

signal the different order to the user equipment or the network entity.

20 7. An apparatus comprising:
at least one processor; and
at least one memory including computer program code,

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

receive during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the
5 network entity;

receive at the network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code, wherein the at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in
10 which the plurality of bits were positioned during the first transmission.

8. The apparatus according to claim 7, wherein the different order before the second transmission comprises at least one of an inverse of the order in which the plurality of bits are encoded in the first transmission, or the order in which the
15 plurality of bits after the first transmission are decoded, or the inverse of the order in which the plurality of bits are decoded after first transmission.

9. The apparatus according to claim 7, wherein the at least part of the plurality of bits are sorted by granularity of bit or bit group for the second
20 transmission before encoding.

10. The apparatus according to claim 7, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to:

5 combine a log-likelihood ratio of the at least a part of the plurality of bits decoded during the first transmission and the second transmission.

11. The apparatus according to claim 7, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause
10 the apparatus at least to:

 decode at least one of the plurality of bits; and
 store the decoded at least one plurality of bits at the base station.

12. The apparatus according to claim 7, wherein the plurality of bits in the
15 initial transmission that are in a low reliability position range are inversed to be in a high reliability position range during the second transmission.

13. A method comprising:

20 transmitting during a first transmission a plurality of bits encoded as part of a

polar code from a user equipment or a network entity to the network entity or the user equipment;

transmitting in a second transmission at least part of the plurality of bits encoded as part of the polar code or another polar code, wherein the at least part of the plurality of bits are sorted in a different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

14. The method according to claim 13, wherein the different order before the second transmission comprises at least one of an inverse of the order in which the plurality of bits are encoded in the first transmission, or the order in which the plurality of bits are decoded after first transmission, or the inverse of the order in which the plurality of bits are decoded after first transmission.

15. The method according to claim 13, further comprising:
signaling the different order to the user equipment or the network entity.

16. The method according to claim 13, wherein the at least part of the plurality of bits are sorted by granularity of bit or bit group for the second transmission before encoding.

17. The method according to claim 13, wherein a log-likelihood ratio of the at least a part of the plurality of bits decoded are combined from the first transmission and the second transmission.

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18. The method according to claim 13, wherein the plurality of bits in the initial transmission that are in a low reliability position range are inversed to be in a high reliability position range during the second transmission.

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19. The method according to claim 13, further comprising:

inputting at least part of the plurality of bits into a polar encoder as information bits.

20. A method comprising:

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receiving during a first transmission a plurality of bits encoded as part of a polar code at a network entity or a user equipment from the user equipment or the network entity; and

receiving at the network entity or the user equipment during a second transmission at least part of the plurality of bits encoded as part of the polar code or

20

another polar code, wherein the at least part of the plurality of bits are sorted in a

different order before the encoding of the second transmission than an order in which the plurality of bits were positioned during the first transmission.

21. The method according to claim 20, wherein the different order before the
5 second transmission comprises at least one of an inverse of the order in which the plurality of bits are encoded in the first transmission, or the order in which the plurality of bits after the first transmission are decoded, or the inverse of the order in which the plurality of bits are decoded after first transmission.

10 22. The method according to claim 20, wherein the at least part of the plurality of bits are sorted by granularity of bit or bit group for the second transmission before encoding.

23. The method according to claim 20, further comprising:
15 combining a log-likelihood ratio of the at least a part of the plurality of bits decoded during the first transmission and the second transmission.

24. The method according to claim 20, further comprising:
decoding at least one of the plurality of bits; and
20 storing the decoded at least one plurality of bits at the base station.

25. The method according to claim 20, wherein the plurality of bits in the initial transmission that are in a low reliability position range are inversed to be in a high reliability position range during the second transmission.

5

26. An apparatus comprising means for performing a process according to any of claims 12-25.

27. A computer program product encoding instructions for performing a
10 process according to any of claims 12-25.

28. A computer program product embodied in a non-transitory computer-readable medium and encoding instructions that, when executed in hardware, perform a process, the process according to claim 12-25.

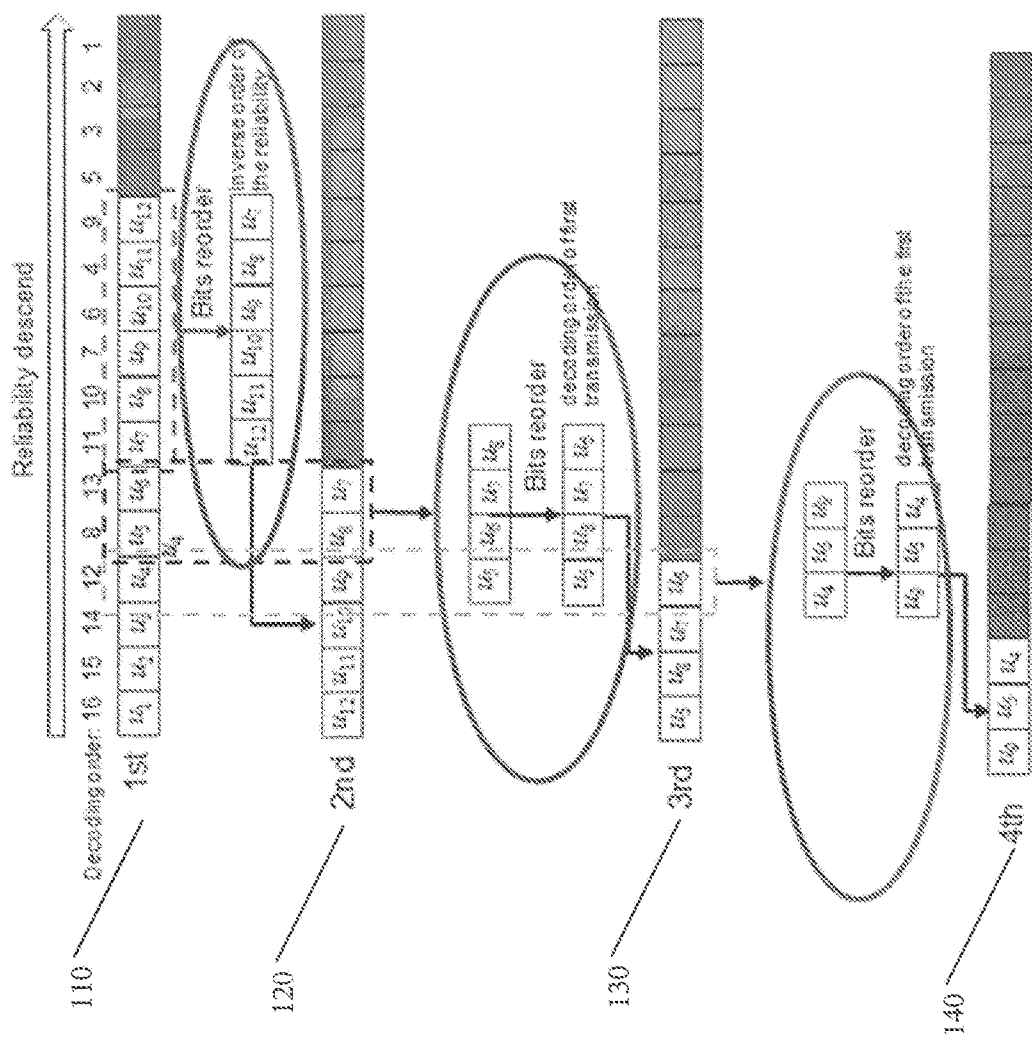


Figure 1

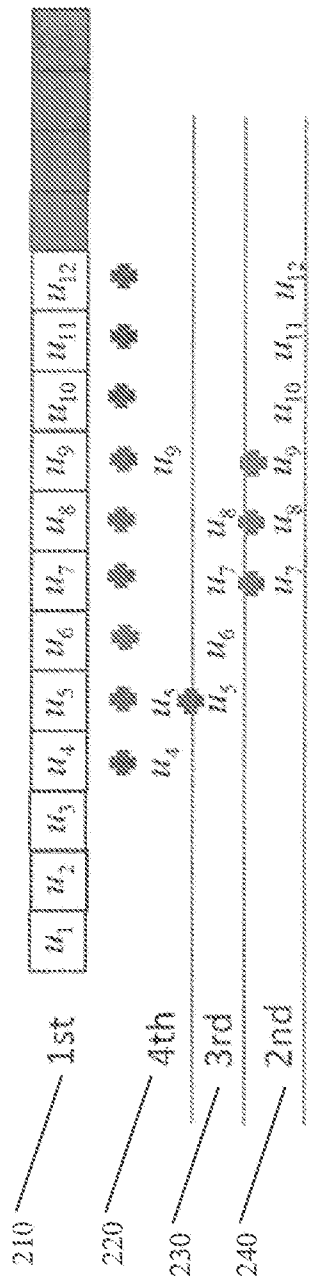


Figure 2

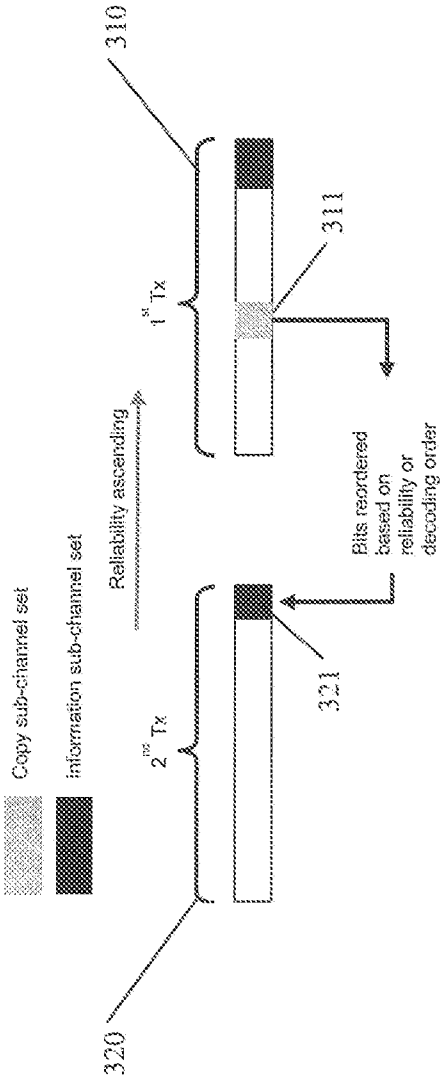


Figure 3

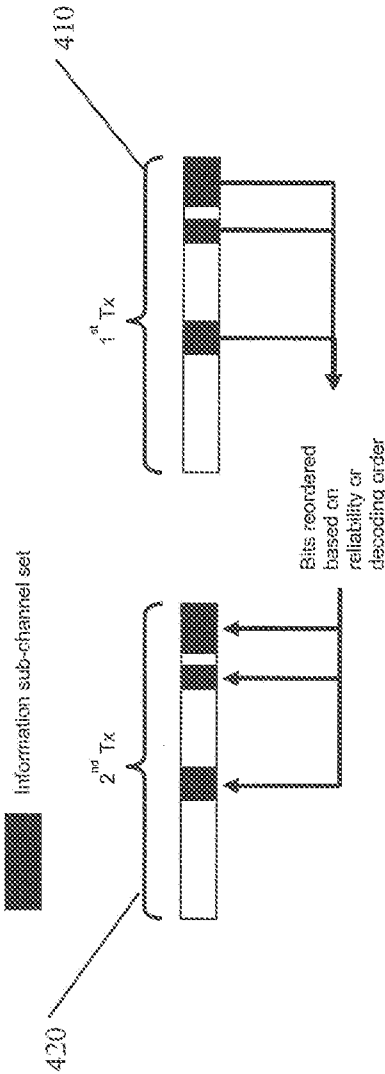


Figure 4

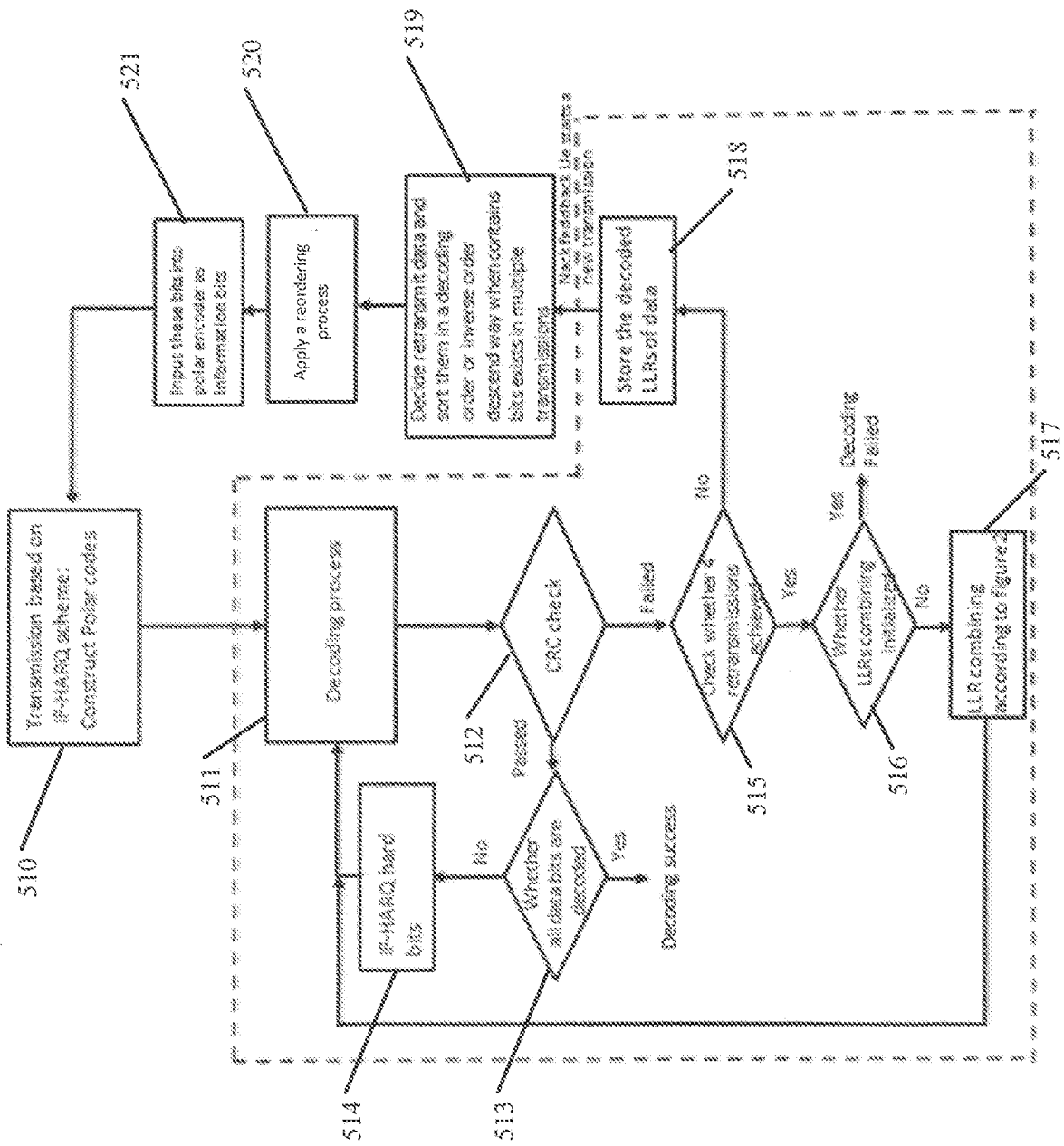


Figure 5

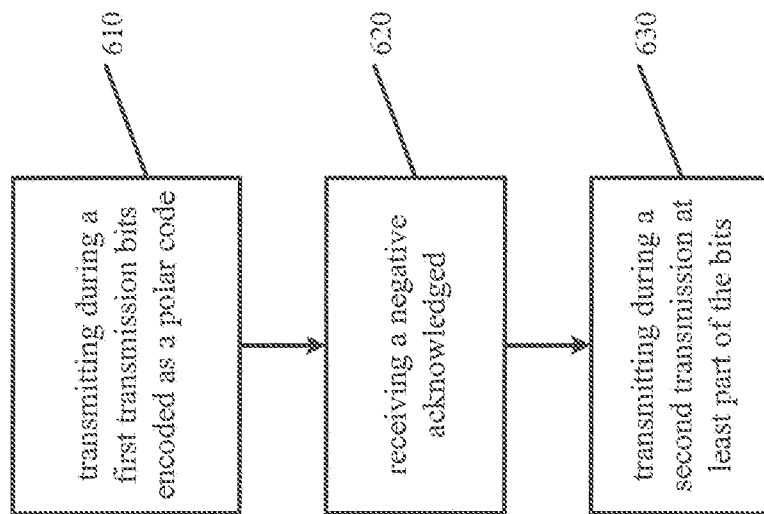


Figure 6

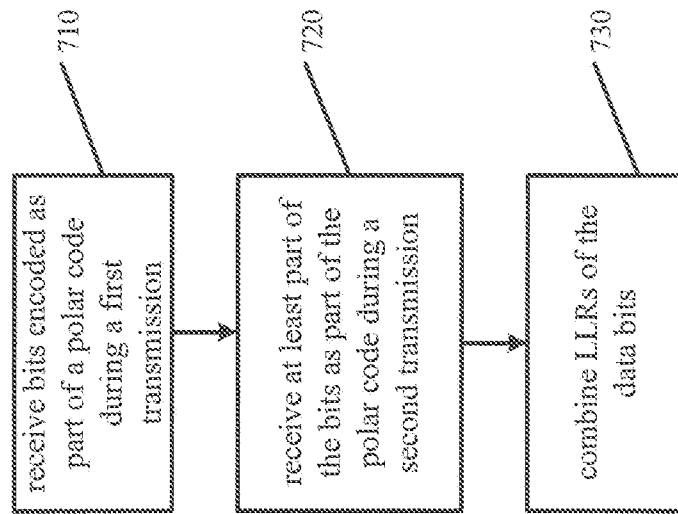


Figure 7

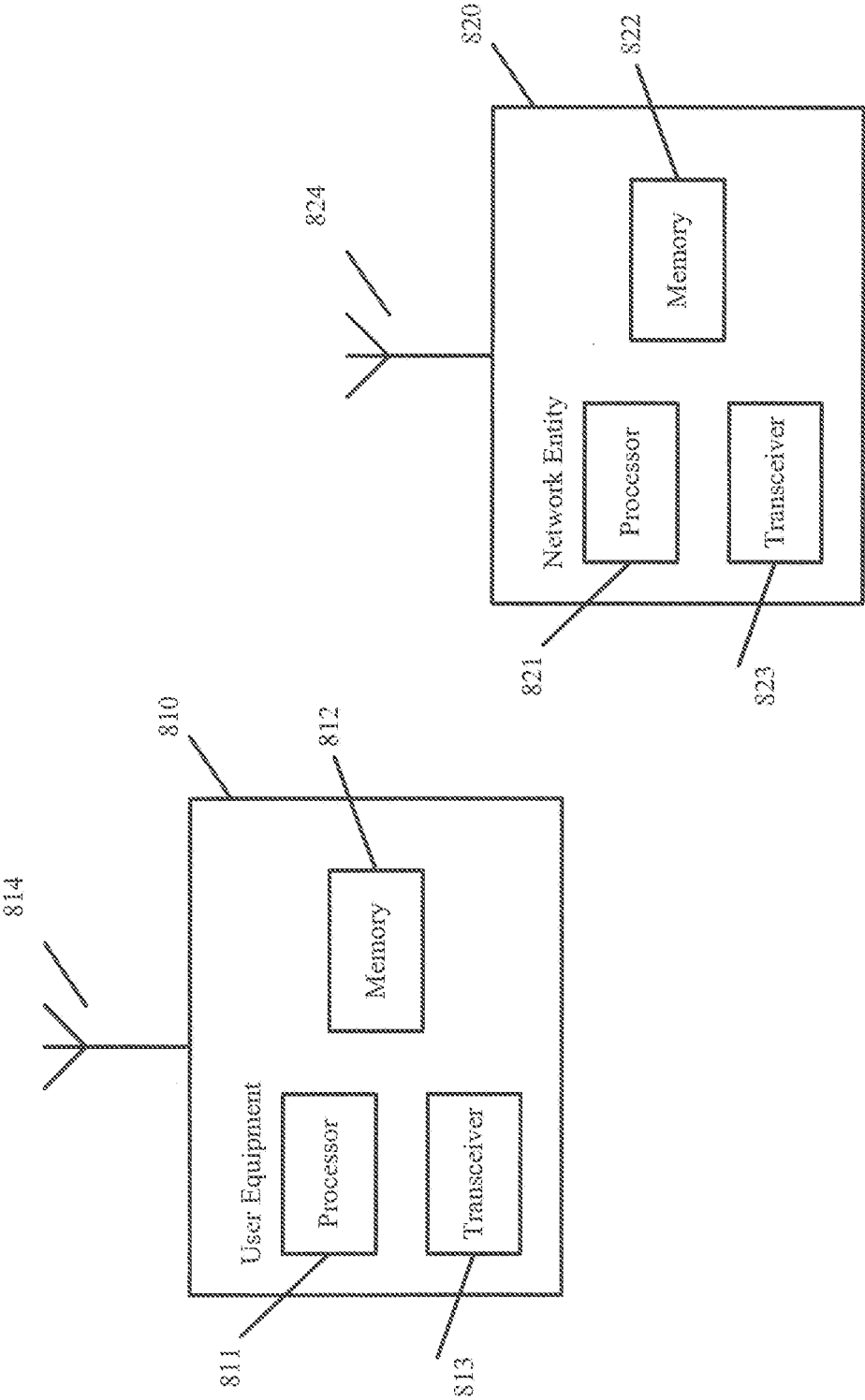


Figure 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/070487

A. CLASSIFICATION OF SUBJECT MATTER

H04L 1/18(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 H04B

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: transmission, first, primary, second, retransmission, polar code, order, different, reverse, same

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2016154972 A1 (HUAWEI TECHNOLOGIES CO., LTD.) 06 October 2016 (2016-10-06) description, page 7 line 3 to page 8 line 13, claims 8, 17	1-2, 6-8, 11, 13-15, 19-21, 24, 26-28
A	US 2016285479 A1 (SAMSUNG ELECTRONICS CO., LTD.) 29 September 2016 (2016-09-29) the whole document	1-28
A	US 2016294418 A1 (MACRONIX INTERNATIONAL CO., LTD.) 06 October 2016 (2016-10-06) the whole document	1-28
A	CN 103281166 A (UNIV. BEIJING POSTS & TELECOMM) 04 September 2013 (2013-09-04) the whole document	1-28
A	ZTE. "Consideration on channel coding for NR" 《3GPP TSG RAN WG1 #86, R1-166413》, 26 August 2016 (2016-08-26), the whole document	1-28

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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"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

02 September 2017

Date of mailing of the international search report

27 September 2017

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/070487

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2016154972	A1	06 October 2016	None			
US	2016285479	A1	29 September 2016	KR	20160115803	A	06 October 2016
				TW	201644219	A	16 December 2016
				CN	106027068	A	12 October 2016
US	2016294418	A1	06 October 2016	CN	106027071	A	12 October 2016
				TW	201635720	A	01 October 2016
CN	103281166	A	04 September 2013	None			