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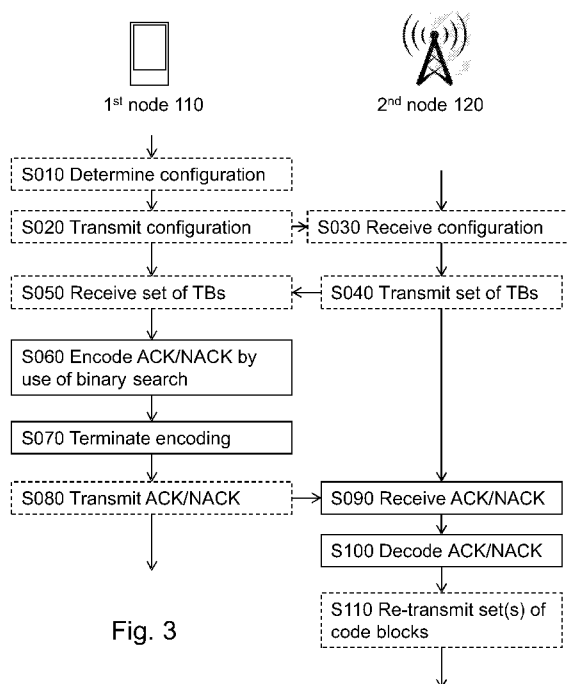


Fig. 3

(57) **Abstract:** A method and a first node (110) for providing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node (110) are disclosed. Each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks. The first node (110) encodes (S060) bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted. Each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared. Said respective bit is included in the ACK/NACK-message in order according to the binary search. The first node (110) terminates (S070) the encoding (S060) of the bits for the ACK/NACK-message by use of the binary search when said each set of code blocks consists of one code block, or a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits. A corresponding method and a second node (120) are also disclosed.



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# METHODS, FIRST AND SECOND NODES FOR MANAGING ACK/NACK-MESSAGES

## Technical Field

Embodiments or examples of the present disclosure generally relate to acknowledgment/non-acknowledgement messages (ACK/NACK-messages) of a Hybrid Automatic Repeat request (HARQ) process in a wireless communication system. Specifically, a method and a first node for providing an ACK/NACK-message of a HARQ-process as well as a method and a second node for managing the ACK/NACK-message are disclosed.

## Background

A transport block (TB) is a set of information bits to be transmitted in one TTI and its size is specified by transport block size (TBS). TBS of Long Term Evolution can be found in Table 1 below, which illustrates a portion of Table 7.1.7.2.1-1 in Third Generation Partnership Project (3GPP) Technical Specification (TS) 36.213. A first portion of the 3GPP-table is illustrated below.

**Table 7.1.7.2.1-1: Transport block size table (dimension 34×110)**

| $I_{TBS}$ | $N_{PRB}$ |     |     |     |     |     |      |      |      |      |
|-----------|-----------|-----|-----|-----|-----|-----|------|------|------|------|
|           | 1         | 2   | 3   | 4   | 5   | 6   | 7    | 8    | 9    | 10   |
| 0         | 16        | 32  | 56  | 88  | 120 | 152 | 176  | 208  | 224  | 256  |
| 1         | 24        | 56  | 88  | 144 | 176 | 208 | 224  | 256  | 328  | 344  |
| 2         | 32        | 72  | 144 | 176 | 208 | 256 | 296  | 328  | 376  | 424  |
| 3         | 40        | 104 | 176 | 208 | 256 | 328 | 392  | 440  | 504  | 568  |
| 4         | 56        | 120 | 208 | 256 | 328 | 408 | 488  | 552  | 632  | 696  |
| 5         | 72        | 144 | 224 | 328 | 424 | 504 | 600  | 680  | 776  | 872  |
| 6         | 328       | 176 | 256 | 392 | 504 | 600 | 712  | 808  | 936  | 1032 |
| 7         | 104       | 224 | 328 | 472 | 584 | 712 | 840  | 968  | 1096 | 1224 |
| 8         | 120       | 256 | 392 | 536 | 680 | 808 | 968  | 1096 | 1256 | 1384 |
| 9         | 136       | 296 | 456 | 616 | 776 | 936 | 1096 | 1256 | 1416 | 1544 |

Table 1

$N_{PRB}$  is the number of allocated Physical Resource Blocks (PRBs) and  $I_{TBS}$  is an index of the used Modulation and Coding Scheme (MCS). Simply to say, TBS value increases when a high order MCS is used and/or more PRBs are allocated.

A code block (CB) is a subset of TB information bits which are protected by a separate cyclic redundancy check (CRC) and there could be several CBs in each TB. The CB size is limited by a pre-defined maximum value so when the TBS increases, the number of CBs increases too. A few CBs can be further grouped into a code block group (CBG). An illustration is found in the table below.

|      |     |     |      |     |     |
|------|-----|-----|------|-----|-----|
| TB   |     |     |      |     |     |
| CBG1 |     |     | CBG2 |     |     |
| CB1  | CB2 | CB3 | CB4  | CB5 | CB6 |

Table 2

In LTE, TB is the basic unit for ACK/NACK feedback, so if one TB is incorrectly received, a Nack will be indicated and if one TB is correctly received, an Ack will be indicated. The whole TB indicated by a Nack is retransmitted. The lesson learned from LTE is that it is highly inefficient to transmit the whole TB because normally not all CBs in a TB are incorrect. So it was agreed by 3GPP to support CBG level ACK/NACK feedback to improve the efficiency. Currently it is assumed that one ACK/NACK bit is allocated to one CBG as illustrated below. According to the 1st agreement below, the CBG size could be as small as one CB or as big as the whole TB.

In new radio (NR), first, there could be much more CBs in one TB as estimated by QC in R1-1705619 “when eMBB data rate is high, each data slot could contain tens to hundreds of CBs” due to the much wider bandwidth. Secondly, NR is going to support enhanced Mobile Broadband (eMBB) and Ultra Reliable Low Latency Communication (URLLC) multiplexing, and URLLC transmission may puncture the ongoing eMBB transmission in the serving cell and may also cause bursty interference to the neighbour cells. These two points make the CBG based HARQ more attractive in NR.

Relevant agreements from RAN1#88b, Spokane, Apr 2017 meeting are copied below:

**Agreements:**

- Confirm the working assumption as below.
  - CBG-based transmission with single/multi-bit HARQ-ACK feedback is supported in Rel-15, which shall have the following characteristics:
    - Only allow CBG based (re)-transmission for the same TB of a HARQ process
    - CBG can include all CB of a TB regardless of the size of the TB – In the such case, UE reports single HARQ ACK bits for the TB
    - CBG can include one CB
    - CBG granularity is configurable

**Agreements:**

- The UE is semi-statically configured by RRC signalling to enable CBG-based retransmission.
- The above semi-static configuration to enable CBG-based retransmission is separate for downlink (DL) and uplink (UL).

**Agreements:**

- For grouping CB(s) into CBG(s), the following options can be considered.
  - Option 1: With configured number of CBGs, the number of CBs in a CBG changes according to TBS.
    - For further study (FFS) for the case of re-transmission or the case when the number of CBs is smaller than the configured number of CBGs

- Option 2: With configured number of CBs per CBG, the number of CBGs changes according to TBS.
- Option 3: The number of CBGs and/or the number CBs per CBG are defined according to TBS.
  - FFS: for the case of re-transmission
- FFS on details of each option
- FFS: CBG is approximately aligned with symbol(s)
- Other options are not precluded

The first agreement is to confirm the support of CBG based HARQ-ACK/NACK, the second agreement is to clarify that CBG based HARQ-ACK/NACK could be separately configured for DL and UL, and the third agreement lists a few options to define the CBG size, i.e., the number of CBs in each CBG.

The CBG size is a trade-off between HARQ ACK/NACK size and transmission efficiency. Obviously, if the CBG size is too small, there will be a lot CBGs in each TB and a big ACK/NACK payload will be produced but a higher efficiency can be achieved with less unnecessary CBs retransmitted. But if the CBG size is too big, the inefficiency problem similar as TB based HARQ-ACK/NACK is hardly solved.

An example is given below with reference to **Figure 1**, with 5 outstanding TBs per HARQ message, 4 CBGs per TB and 10 CBs per CBG. In total, 20 ACK/NACK bits are required to indicate all CBGs with the current method and any incorrect CB will result in all CBs within the CBG retransmitted.

The following drawbacks of this design are envisaged:

- 1) Highly variable ACK/NACK payload size with many different combinations of the number of scheduled PRBs and the MCS used, which will result in a more complicated specification.
- 2) Inefficient transmission for both control and data
  - a. 4 bits ACK/NACK are still used to indicate a correct TB (in grey) which results in very inefficient UL control transmission
  - b. A single ACK/NACK bit is used to indicate one CBG (in red) which results in inefficient DL data retransmission.

Although DL data transmission with UL feedback is considered in this figure, this invention can be used by UL data transmission with DL feedback in a similar way.

### Summary

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

According to an aspect, there is provided a method for providing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQuest, "HARQ", process relating to a set of transport blocks received by a first node. Each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks. The first node, performing the method, encodes bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted. Each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared, i.e. equal to zero. Said respective bit is included in the ACK/NACK-message in order according to the binary search. The first node terminates the encoding of the bits for the ACK/NACK-message by use of the binary search when said each set of code blocks consists of one code block, or a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits.

According to another aspect, there is provided a method for managing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQuest, "HARQ", process relating to a set of transport blocks received by a first node from a second node. Each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks. The second node, performing the method, receives the ACK/NACK-message from the first node. The second node further decodes bits of the ACK/NACK-message, e.g. while beginning with a most significant bit thereof, to find one or more sets of code blocks to be re-transmitted, wherein each set of code blocks, i.e. to be re-transmitted, is indicated by a respective bit that is cleared, i.e. equal to zero. Said respective bit is taken in order from the bits of the ACK/NACK-message according to a tree structure derived from a binary search used when encoding the ACK/NACK-message.

Accordingly, the embodiments herein provide a code block based ACK/NACK coding, i.e. coding of the ACK/NACK-message, that efficiently uses bit of the ACK/NACK-message by implementing the binary search, e.g. in a stepwise manner as described herein.

As a result, embodiments herein also improve re-transmission efficiency, i.e. re-transmissions may occur at CB-level instead of CBG-level as described in the background section. At the same time, the embodiments enable a size, e.g. in number of bits, of the ACK/NACK-message to be flexible. The size of the ACK/NACK-message may be flexible in that the size is selectable, or configurable, by the first and/or second node.

According to further aspects, there is provided computing device, such as the first node and/or the second node, including a processor unit, a storage unit and a communications interface, where the processor unit, storage unit, and communications interface are configured to perform the method(s) herein.

The methods described herein may be performed by software in machine readable form on a tangible storage medium or computer readable medium e.g. in

the form of a computer program comprising computer program code means adapted to perform all the steps of any of the methods described herein when the program is run on the computing device, and where the computer program may be embodied on a computer readable medium. Examples of tangible, or non-transitory, storage media include disks, thumb drives, memory cards etc. and do not include propagated signals. The software can be suitable for execution on a parallel processor or a serial processor such that the method steps may be carried out in any suitable order, or simultaneously.

According to a further aspect, there is provided a computer readable medium comprising a computer program, program code or instructions stored thereon, which when executed on a processor, causes the processor to perform the methods herein.

This acknowledges that firmware and software can be valuable, separately tradable commodities. It is intended to encompass software, which runs on or controls “dumb” or standard hardware, to carry out the desired functions. It is also intended to encompass software which “describes” or defines the configuration of hardware, such as hardware description language (HDL) software, as is used for designing silicon chips, or for configuring universal programmable chips, to carry out desired functions.

The preferred features may be combined as appropriate, as would be apparent to a skilled person, and may be combined with any of the aspects of the invention.

#### Brief Description of the Drawings

Further details, aspects and embodiments will be described, by way of example only, with reference to the drawings. Elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. Like reference numerals have been included in the respective drawings to ease understanding.

Figure 1 is a block diagram illustrating CBG based ACK/NACK according to prior art.

Figure 2 is a schematic overview of a wireless communication system.

Figure 3 is a simplified combined signalling and flow chart illustrating exemplary methods when implemented in the wireless communication system of Figure 2.

Figure 4 is a simplified block diagram illustrating a set of transport blocks including two incorrect code blocks.

Figure 5 is a view illustrating an exemplifying coding of an ACK/NACK-message relating to the set of transport blocks of Figure 4.

Figure 6 is a view illustrating another exemplifying coding of an ACK/NACK-message relating to the set of transport blocks of Figure 4.

Figure 7 is a view illustrating the exemplifying coding of Figure 5 with respect to a set of transport blocks including multiple incorrect code blocks in different code block groups.

Figure 8 is an overview illustrating decoding of an ACK/NACK-message.

Figure 9 is a further overview illustrating further exemplifying codings of an ACK/NACK-message.

Figure 10 is a flowchart illustrating a simplified method performed by the first node.

Figures 11a and 11b are simplified block diagrams illustrating embodiments of the first node.

Figure 12 is a flowchart illustrating a simplified method performed by the second node.

Figures 13a and 13b are simplified block diagrams illustrating embodiments of the first node.

### Detailed Description

Those skilled in the art will recognise and appreciate that the specifics of the examples described are merely illustrative of some embodiments and that the teachings set forth herein are applicable in a variety of alternative settings.

Referring now to Figure 2, an exemplifying **wireless communication system 100** is shown.

The wireless communication system 100 comprises a **first node 110** and a **second node 120**. In this example, the first node 110 is illustrated as a user equipment and the second node 120 is illustrated as a base station. In other examples, the first node may be a base station and the second node 120 may be a user equipment.

Hence, as used herein the term “node” may refer to a user equipment, a base station, a relay node, a radio network controller, a network node, a radio network node, a radio communication device and the like.

The wireless communication system 100 may be any cellular or non-cellular 3GPP based wireless communication system, such as a 3<sup>rd</sup> generation system (3G), a 4<sup>th</sup> generation system (4G), a 5<sup>th</sup> generation system (5G), a NR system, a Long-Term Evolution (LTE), e.g. LTE Frequency Division Duplex (FDD), LTE Time Division Duplex (TDD), LTE Half-Duplex Frequency Division Duplex (HD-FDD), LTE operating in an unlicensed band, or a Wideband Code Division Multiple Access (WCDMA), Universal Terrestrial Radio Access (UTRA) TDD, Ultra-Mobile Broadband (UMB), Global System for Mobile communications (GSM) network, GSM/Enhanced Data Rate for GSM Evolution (EDGE) Radio Access Network (GERAN) network, EDGE network, a network comprising of any combination of Radio Access Technologies (RATs) such as e.g. Multi-Standard Radio (MSR) base stations, multi-RAT base stations etc., any 3<sup>rd</sup> Generation Partnership Project (3GPP) cellular network, WiFi networks, Worldwide Interoperability for Microwave Access (WiMax), or any other cellular network or system or an evolution of any one of the aforementioned networks or systems.

As used herein, the term “user equipment” may refer to a wireless communication device, a machine-to-machine (M2M) device, a mobile phone, a cellular phone, a smartphone, a laptop or personal computer (PC) equipped with an internal or external mobile broadband modem, a tablet PC with radio communication

capabilities, a portable electronic radio communication device, a sensor device equipped with radio communication capabilities or the like. The term “user” may indirectly refer to the wireless device. Sometimes, the term “user” may be used to refer to the user equipment or the like as above. It shall be understood that the user may not necessarily involve a human user. The term “user” may also refer to a machine, a software component or the like using certain functions, methods and similar.

**Figure 3** illustrates embodiments of the method when implemented in the wireless communication system 100 of Figure 2. The first node 110 performs a method for providing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node 110. The second node 120 performs a method for managing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node 110 from a second node 120.

Each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks.

According to the various embodiments herein, one or more of the following steps may be performed as applicable.

In a step **S010**, the first node 110 may determine a configuration relating to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group and the like.

In a step **S020**, the first node 110 may transmit the configuration to the second node 120.

In a step **S030**, the second node 120 may receive a configuration from the first node 110, wherein the configuration relates to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group and the like.

In a step **S040**, the second node 120 may transmit the set of transport blocks.

In a step **S050**, subsequent to step S040, the first node 110 may receive the set of transport blocks to be managed in step S060 below.

In a step **S060**, the first node 110 encodes bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted. Each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared, i.e. equal to zero. Said respective bit is included in the ACK/NACK-message in order according to the binary search.

It may be noted that said each set of code blocks not to be re-transmitted is indicated by setting the respective bit, i.e. assigning the respective bit a value equal

to one. Any code blocks further down a branch without any incorrect code blocks will not be indicated at all.

In some embodiments, the first node 110 encodes the bits of the ACK/NACK-message by including said respective bits in order into the ACK/NACK-message while taking into account on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group, and the like.

In this manner, the first node takes into account how the ACK/NACK-message may be built up when encoding.

According to some embodiments, hereinafter referred to as “line-embodiments”, said respective bits may be included into the ACK/NACK-message line by line from a tree structure obtained by, or derived from, the binary search. As will be explained in more detail with reference to Figure 5 below, the expression “line by line” means row by row, level by level or similar with respect to the tree structure of the binary search.

According to some embodiments, hereinafter referred to as “branch-embodiments”, said respective bits may be included into the ACK/NACK-message branch by branch from the tree structure. As will be explained in more detail with reference to Figure 6 below, the expression “branch by branch” means path by path or similar with respect to the tree structure.

In some embodiments, the first node 110 encodes the ACK/NACK-message by encoding a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block of the set of transport blocks. This means that there is one bit, i.e. the respective transport block bit, for each transport block of the set of transport blocks, wherein said one bit indicates whether or not, by zero or one, respectively, said each transport block comprises at least one incorrect code block. As an example, a set of transport block bits may comprise each respective transport block bit, wherein the set of transport block bits may constitute the most significant bits of the ACK/NACK-message.

These embodiments may be combined with the line-embodiments, the branch-embodiments or other embodiments herein. In case these embodiments are combined with the line-embodiments and/or the branch-embodiments, the encoding begin with setting or clearing the respective transport block bits and then proceeds with encoding of the respective bits for said each set of code blocks.

In some embodiments, hereinafter referred to as “indicator-embodiments”, the first node 110 may encode the ACK/NACK message by encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be

re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation:

$$2^n \geq \frac{a(a+1)}{2} \quad (\text{Eq. 1})$$

wherein  $a$  represents the number of code blocks of each transport block.

It may be noted that the number of code blocks of each transport block is equal to the number code block groups of each transport block multiplied by the number of code blocks of each code block group.

The relation according to equation 1 (Eq. 1) may be expressed as:

$$n = \underset{n}{\operatorname{argmin}} \left( 2^n \geq \frac{a(a+1)}{2} \right) \quad (\text{Eq. 2})$$

According to some examples of the indicator-embodiments, each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one. These examples are explained in more detail with reference to Figure 9, "option 1a".

According to some examples of the indicator-embodiments, a first indicator of the set of indicators may be preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one. These examples are explained in more detail with reference to Figure 9, "option 1b".

According to some examples of the indicator-embodiments, the set of indicators consists of one indicator, i.e. a length of the set of indicators is equal to one. This means that the set of indicators comprises only one indicator. These examples are explained in more detail with reference to Figure 9, "option 2".

In a step **S070**, the first node 110 terminates the encoding S060 of the bits for the ACK/NACK-message by use of the binary search when

- said each set of code blocks consists of, i.e. comprises only one, one code block, or
- a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits.

In the example of Figure 5 below, said each set of code blocks consists of one code block and the encoding is terminated.

In the example of Figure 7 below, the number of bits, included in the ACK/NACK-message, has reach the predetermined number of bits, i.e. in that example 20 bits.

In a step **S080**, the first node 110 may transmit the ACK/NACK-message to a second node 120. The second node 120 transmitted the set of transport blocks.

In a step **S090**, the second node 120 receives the ACK/NACK-message from the first node 110.

In a step **S100**, the second node 120 decodes bits of the ACK/NACK-message, e.g. while beginning with a most significant bit of the ACK/NACK-message,

to find one or more sets of code blocks to be re-transmitted. Each set of code blocks, i.e. to be re-transmitted, is indicated by a respective bit that is cleared, i.e. equal to zero. Said respective bit is taken in order from the bits of the ACK/NACK-message according to a tree structure derived from a binary search used when encoding the ACK/NACK-message.

In some embodiments, the second node 120 may decode bits of the ACK/NACK-message by taking the bits in order according to the tree structure based on at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block, and the number of code blocks of each code block group

The same or similar embodiments as disclosed above for the first node 110 also apply to the second node 120. These embodiments are disclosed with reference to Figure 12 below.

In a step **S110**, the second node 120 may re-transmit said one or more sets of code blocks to the first node 110. Typically, said one or more sets of code blocks may be included in one or more further transport blocks, which may or may not also carry other data than the data of said one or more code blocks to be re-transmitted.

In an example relating to the first node 110, i.e. a transmitter side with respect to transmission of the ACK/NACK-message, there are 5 TBs per HARQ-ACK/NACK message (ACK/NACK-message for short), 4 CBGs per TB and 10 CBs (CB 0 to CB 9) per CBG. According to prior art, as illustrated in Figure 1, 20 ACK/NACK bits ( $5 \times 4$ ) will be required.

In this specific example, 2 CBs are wrong as highlighted with vertical stripes in **Figure 4**.

With the specific example, the bits of the ACK/NACK-message are set as illustrated below in **Figure 5**. Hence, with reference to Figure 5, the encoding of the ACK/NACK-message may be performed according to one or more of the following actions, or steps.

- 1) First, 5 bits are set for 5 TBs, it has value of "1" if all CBs are correct and value "0" if any CB of this TB is incorrect, and in this example, the 5 output bits are "11011".
- 2) Second, 2 bits are allocated to each incorrect TB (the one with "0" in step 1), the first bit is set according to the front half number of CBGs and the second bit is set according to the second half number of CBGs. In this example, the single incorrect CBG is in the CBG set of CBG 0/1 (CBG 0 and CBG 1, same below) so the 2 bits are set as "01".
- 3) Third, 2 bits are allocated to each said CBG set in step 2, the first bit is set according to the front half number of the said CBG set and the second bit is set according to the second half number of CBG set. In this example, CBG 0

is correct and CBG 1 has at least one incorrect CB so the 2 bits are set as “10”.

- 4) Fourth, this kind of split keeps on until all incorrect CBs are clearly indicated. In this example, all 10 CBs of CBG 1 can be further split into first 5 CBs and second 5 CBs, since both 5-CBs have incorrect CBs, so it outputs “00” in this step.
- 5) Fifth, 4 bits are allocated in this step as there are two “0s” in the last step and these 4 bits are used to indicate CB 0/1/2, CB 3/4, CB 5/6/7 and CB 8/9 in order. According to the positions of incorrect CBs, it outputs “0101” in this step.
- 6) At last, 4 bits are allocated in this step for the two “0s” again in the last step and these 4 bits are used to indicate CB 0/1, CB 2, CB5/6 and CB7 in order. Accordingly, it outputs “1010” in this step which means CB 2 and CB 7 are incorrect. Since all incorrect CBs are indicated, the whole procedure can be finished after this step.

The vector of coding bits above is formed by concatenating all bits above line by line, or expressed differently row by row or level by level, of the tree resulting from the binary search. The steps 1) – 6) above illustrate action S060 of Figure 3 in more detail according to an example of the line-embodiments.

According to the branch-embodiments, the bits of the ACK/NACK-message can also be formed by concatenating all bits branch by branch from for example left to right as shown in **Figure 6**.

- 1) Read 5 bits for the TB level ACK/NACK.
- 2) Read the most left branch of the most left “0” in Step 1.
- 3) - 8) Read the most left branch from the most bottom “incomplete joint” of the branch in last step and if all joints in this branch are all complete, go back to the branch one step back.
  - a. e.g., branch #2 shown below has two joints, A and B, which are both incomplete (i.e., has only 1 branch), so the next most left branch is branch 3 from joint #A (not included).
- 9) Read the last branch. In this example, the only branch with incomplete joint is branch #2, branch 9 from joint #B (not included).

The output bits are given in table below from each corresponding step:

| Step   | 1 |   |   |   |   | 2 |   | 3 |   |   |   | 4 | 5 | 6 |   | 7 | 8 | 9 |   |
|--------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Output | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |

Table 3

The line-embodiments may be preferred when different CBs have an independent error probability such that all CBs can be indicated equally. The branch-embodiments may be preferred when adjacent CBs have a correlated error probability such that the first error can be quickly identified. Which embodiment to



this example, the number of CBG per TB, 4 in this example, and the number of CBs per CBG, 10 in this example, which are informed during setup, e.g. using Radio Resource Control signalling. This means that the same exemplifying number of transport blocks, code block groups and code blocks are used in this example again.

While turning to **Figure 8**, it is seen that one or more of the following steps may be performed.

- 1) First the second node 120 may map the first 5 bits to 5 TBs, so with "11010", TB 0/1/3 are marked as acknowledged and TB 2/4 are marked as unacknowledged.
- 2) Second, for the 2 "0"s in the last step, the following 4 bits may be mapped to the 4 CBG sets of TB2 and TB4 in order. "0100" mean errors in CBG 0/1 set of TB 2 (CBG 2/3 set are acknowledged), CBG 0/1 set and CBG 2/3 set of TB 4.
- 3) Third, for the 3 "0" bits in the last step, the second node 120 may map the following 6 bits "101001" to CBG 0/1 of TB 2, CBG 0/1 of TB4 and CBG 2/3 of TB 4 in order so CBG 1 of TB2 and CBG 1/2 of TB4 are marked as unacknowledged while others are marked as acknowledged.
- 4) Fourth, there are 3 "0" bits in last step, the second node 120 will use the remaining 5 bits together with a "0" to further down select the incorrect CBs. "010110" means CB 0/1/2/3/4 of CBG 1 of TB 2, CBG 0/1/2/3/4 of CBG 1 of TB 4 and CB 5/6/7/8/9 of CBG 2 of TB4 have errors and the second node 120 may retransmit all these CBs.

As can be seen from this example, any payload size is decodable and again, it enables full flexibility trade-off between ACK/NACK payload size and data transmission efficiency.

**Figure 9** illustrates some indicator-embodiments. In general, a few continuous CBs may be indexed by a "starting position" + a "length", and since the starting position determines the value range of the length, these two values may be jointly encoded, e.g., RIV (Resource Indication Value) in LTE.

In this example, one TB totally has 40 CBs, indexed with 0 to 39, when the starting position is L, the length much be in the range from 1 to 40-L, so the number of all combinations of "starting position" + "length" is 820 (= 40+39+...+1) and totally 10 bits are required.

The joint indicator of the set of continuous incorrect CBs is herein referred to as EIV, Error Indication Value.

According to a first example, referred to as "option 1", each incorrect CBs set are indicated separately. So the example in the following figure is coded as:

*Option 1A: "11011" + "0" + "EIV1 (CB#12 to CB#17)" + "0" + "EIV2 (CB#23 to CB#26)" + "1"*

In total, 28 bits are required, each EIV is started by a "0" and "1" means no further EIV of this TB.

Or a pre-defined indicator can be introduced to indicate how many EIVs are included for this TB.

*Option 1B* “11010” + “01” + “EIV1 (CB#12 to CB#17)” + “EIV2 (CB#23 to CB#26)”

Two bits indicator is introduced to indicate that there are two EIVs for the incorrect TB.

Totally, two bits can indicate 1 to 4 EIVs, “01” above means two EIVs. Obviously, Option 1B will limit the number EIVs that can be indicated but the benefit is that it can save a few bits from Option 1A.

According to a second example, referred to as “option 2”, all incorrect CBs are indicated together, one single EIV is used to cover all incorrect CBs and obviously, correct CBs in between will be reported as errors too. The same example is coded as:

“11011” + “EIV (CB#12 to CB#26)”

In total 15 bits are required. Since there is only one EIV for each TB, no additional bit is required to start and terminal an EIV as in Option 1, but a drawback is that 5 correct CBs are retransmitted which will cause some inefficiency concerning resources usage.

As can be seen from the above examples, the number of coded ACK/NACK bits varies but the first node 110 may only select a number of ACK/NACK bits from the beginning to transmit and discard all others. This may aid in reducing number of ACK/NACK payload sizes that may be specified.

The embodiments herein apply the binary search algorithm known from computer science. In this manner, a fine granularity for indication of CBs is achieved and furthermore an improved data transmission efficiency with the given ACK/NACK payload size is achieved.

The embodiments of Figure 9 may have a smaller encoded ACK/NACK payload in some scenarios as compared to other embodiments herein, but these embodiments do not support a flexible cut of the payload, as explained e.g. with reference to Figure 7. This means that the entire encoded ACK/NACK payload shall be sent completely, i.e. without cutting.

**Figure 10** illustrates exemplifying methods, performed by the first node 110, for providing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node 110. According to the various embodiments herein, one or more of the following steps may be performed as applicable. The same or similar reference numerals have been used to denote the same or similar steps, or actions.

As mentioned, each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks.

In a step **S010**, the first node 110 may determine a configuration relating to at least one of the number of transport blocks of each ACK/NACK-message, the

number of code block groups of each transport block and the number of code blocks of each code block group.

In a step **S020**, the first node 110 may transmit the configuration to the second node 120.

In a step **S060**, the first node 110 encodes bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted. Each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared, i.e. equal to zero. Said respective bit is included in the ACK/NACK-message in order according to the binary search.

In some embodiments, the first node 110 encodes the bits of the ACK/NACK-message by including said respective bits in order into the ACK/NACK-message while taking into account on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group.

Expressed differently, the encoding S060 of bits of the ACK/NACK-message may comprise including said respective bits in order into the ACK/NACK-message while taking into account on at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block, and the number of code blocks of each code block group.

According to the line-embodiments, said respective bits may be included into the ACK/NACK-message line by line from a tree structure obtained by, or derived from, the binary search.

According to the branch-embodiments, said respective bits may be included into the ACK/NACK-message branch by branch from a tree structure obtained by, or derived from, the binary search.

In some embodiments, the first node 110 encodes the ACK/NACK-message by encoding a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block of the set of transport blocks. This means that there is one bit, i.e. the respective transport block bit, for each transport block of the set of transport blocks, wherein said one bit indicates whether or not, by zero or one, respectively, said each transport block comprises at least one incorrect code block.

As an example, a set of transport block bits may comprise each respective transport block bit, wherein the set of transport block bits constitutes the most significant bits of the ACK/NACK-message.

Expressed differently, the encoding of the ACK/NACK-message may comprise encoding the respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit said at least one code block of each respective transport block of the set of transport blocks.

According to the indicator-embodiments, the first node 110 may encode the ACK/NACK message by encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation according to Eq. 1.

It may be noted that the number of code blocks of each transport block is equal to the number code block groups of each transport block multiplied by the number of code blocks of each code block group.

Again, expressed differently, the encoding of the ACK/NACK-message may comprise encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation above, wherein  $a$  represents number of code blocks of each transport block.

According to some examples of the indicator-embodiments, each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one.

According to some examples of the indicator-embodiments, a first indicator of the set of indicators may be preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

According to some examples of the indicator-embodiments, the set of indicators consists of one indicator, i.e. a length of the set of indicators is equal to one. This means that the set of indicators comprises only one indicator.

In a step **S070**, the first node 110 terminates the encoding S060 of the bits for the ACK/NACK-message by use of the binary search when

- said each set of code blocks consists of one code block, or
- a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits.

In a step **S080**, the first node 110 may transmit the ACK/NACK-message to a second node 120. The second node 120 transmitted the set of transport blocks.

**Figures 11a and 11b** illustrate embodiments of the first node 110.

Figure 11a illustrates various components of an exemplary computing-based device 1100 which may be implemented to include the functionality of the first node 110 as disclosed herein.

The computing-based device 1100 comprises one or more processors 1102 which may be microprocessors, controllers or any other suitable type of processors for processing computer executable instructions to control the operation of the device in order to perform measurements, receive measurement reports, schedule

and/or allocate communication resources as described in the process(es) and method(s) as described herein.

In some examples, for example where a system on a chip architecture is used, the processors 1102, or processor units, may include one or more fixed function blocks which implement the methods and/or processes as described herein in hardware, rather than software or firmware.

Platform software and/or computer executable instructions comprising an operating system 1104a or any other suitable platform software may be provided at the computing-based device to enable application software to be executed on the device. Depending on the functionality and capabilities of the computing device 1100 and application of the computing device, software and/or computer executable instructions may include functionality to perform the methods of Figure 10.

For example, the computing device 1100 may be used to implement the first node 110 and may include software and/or computer executable instructions that may include functionality to perform the methods of Figure 10.

The software and/or computer executable instructions may be provided using any computer-readable media that is accessible by computing based device 1100. Computer-readable media may include, for example, computer storage media such as memory 1104 and communications media. Computer storage media, such as memory 1104, includes volatile and non-volatile, removable and non-removable media implemented in any method or technology. A data store 1104A of the memory 1104 is configured for storage of information such as computer readable instructions, data structures, program modules or other data.

Computer storage media may include, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other non-transmission medium that can be used to store information for access by a computing device. In contrast, communication media may embody computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave, or other transport mechanism. As defined herein, computer storage media does not include communication media. Although the computer storage media, such as the memory 1104, is shown within the computing-based device 1100 it will be appreciated that the storage may be distributed or located remotely and accessed via a network or other communication link, e.g. using communication interface 1106.

The computing-based device 1100 may also optionally or if desired comprises an input/output controller 1115 arranged to output display information to a display device 1112 which may be separate from or integral to the computing-based device 1100. The display information may provide a graphical user interface. The input/output controller 1115 is also arranged to receive and process input from one or more devices, such as a user input device 1114, e.g. a mouse or a keyboard. This user input may be used to set scheduling for measurement reports, or for allocating communication resources, or to set which communications resources are

of a first type and/or of a second type etc. In an embodiment the display device 1112 may also act as the user input device 1114 if it is a touch sensitive display device. The input/output controller 1115 may also output data to devices other than the display device, e.g. other computing devices via communication interface 1106, any other communication interface, or a locally connected printing device/computing devices etc.

Figure 11b illustrates a schematic block diagram of the first node 110 according to another embodiment. The first node 110 comprises an encoding module 1110, a terminating module 1120, a transmitting module 1130, a determining module 1140, and a receiving module 1150, which are configured to perform one or more of the steps performed by the first node 110 according to Figure 10.

In view of the above, the first node 110 provides the following embodiments.

The first node 110 is configured for providing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node 110.

As mentioned, each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks.

The first node 110 and/or the processor(s) 1102 and/or the determining module 1140 may be configured to determine a configuration relating to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group.

The first node 110 and/or the processor(s) 1102 and/or the transmitting module 1130 may be configured to transmit the configuration to the second node 120.

The first node 110 and/or the processor(s) 1102 and/or the encoding module 1110 may be configured to encode bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted. Each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared. Said respective bit is included in the ACK/NACK-message in order according to the binary search.

In some embodiments, the first node 110 and/or the processor(s) 1102 and/or the encoding module 1110 may be configured to encode the bits of the ACK/NACK-message by including said respective bits in order into the ACK/NACK-message while taking into account on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group.

According to the line-embodiments, said respective bits may be included into the ACK/NACK-message line by line from a tree structure obtained by, or derived from, the binary search.

According to the branch-embodiments, said respective bits may be included into the ACK/NACK-message branch by branch from a tree structure obtained by, or derived from, the binary search.

In some embodiments, the first node 110 and/or the processor(s) 1102 and/or the encoding module 1110 may be configured to encode the ACK/NACK-message by encoding a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block of the set of transport blocks.

According to the indicator-embodiments, the first node 110 and/or the processor(s) 1102 and/or the encoding module 1110 may be configured to encode the ACK/NACK message by encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation according to Eq. 1.

According to some examples of the indicator-embodiments, each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one.

According to some examples of the indicator-embodiments, a first indicator of the set of indicators may be preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

According to some examples of the indicator-embodiments, the set of indicators consists of one indicator, i.e. a length of the set of indicators is equal to one.

The first node 110 and/or the processor(s) 1102 and/or the terminating module 1120 is configured to terminate the encoding of the bits for the ACK/NACK-message by use of the binary search when

- said each set of code blocks consists of one code block, or
- a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits.

The first node 110 and/or the processor(s) 1102 and/or the transmitting module 1130 may be configured to transmit the ACK/NACK-message to a second node 120. The second node 120 transmitted the set of transport blocks.

**Figure 12** illustrates exemplifying methods, performed by the second node 120, for managing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by the first node 110 from the second node 120.

As mentioned, each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks,

According to the various embodiments herein, one or more of the following steps may be performed as applicable. The same or similar reference numerals have been used to denote the same or similar steps, or actions.

In a step **S030**, the second node 120 may receive a configuration from the first node 110, wherein the configuration relates to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group

In a step **S090**, the second node 120 receives the ACK/NACK-message from the first node 110.

In a step **S100**, the second node 120 decodes bits of the ACK/NACK-message, e.g. while beginning with a most significant bit of the ACK/NACK-message, to find one or more sets of code blocks to be re-transmitted. Each set of code blocks is indicated by a respective bit that is cleared. Said respective bit is taken in order from the bits of the ACK/NACK-message according to a tree structure derived from a binary search used when encoding the ACK/NACK-message.

In some embodiments, the second node 120 may decode bits of the ACK/NACK-message by taking the bits in order according to the tree structure based on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group

Expressed differently, the decoding S100 of bits of the ACK/NACK-message comprises taking the bits in order according to the tree structure based on at least one of a number of transport blocks of each ACK/NACK-message, a number of code block groups of each transport block, and a number of code blocks of each code block group.

According to the line-embodiments, the second node 120 may decode the bits of the ACK/NACK-message while taking into account that said respective bits are included into the ACK/NACK-message line by line from the tree structure.

According to the branch-embodiments, the second node 120 may decode the bits of the ACK/NACK-message while taking into account that said respective bits are included into the ACK/NACK-message branch by branch from the tree structure.

In some embodiments, the second node 120 may decode the bits of the ACK/NACK-message while taking into account that the ACK/NACK-message comprises a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block.

According to the indicator-embodiments, the second node 120 may decode bits of the ACK/NACK-message by decoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted,

wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation according to Eq.1.

Expressed differently, the decoding of the bits of the ACK/NACK-message may comprise decoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation according to Eq.1.

According to some examples of the indicator-embodiments, each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one.

According to some examples of the indicator-embodiments, a first indicator of the set of indicators may be preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

According to some examples of the indicator-embodiments, the set of indicators consists of one indicator, i.e. a length of the set of indicators is equal to one. This means that the set of indicators comprises only one indicator.

In a step **S110**, the second node 120 may re-transmit said one or more sets of code blocks to the first node 110.

**Figures 13a and 13b** illustrate embodiments of the second node 120.

Figure 13a illustrates various components of an exemplary computing-based device 1300 which may be implemented to include the functionality of the second node 120 as disclosed herein.

The computing-based device 1300 comprises one or more processors 1302 which may be microprocessors, controllers or any other suitable type of processors for processing computer executable instructions to control the operation of the device in order to perform measurements, receive measurement reports, schedule and/or allocate communication resources as described in the process(es) and method(s) as described herein.

In some examples, for example where a system on a chip architecture is used, the processors 1302, or processor units, may include one or more fixed function blocks (also referred to as accelerators) which implement the methods and/or processes as described herein in hardware, rather than software or firmware.

Platform software and/or computer executable instructions comprising an operating system 1304a or any other suitable platform software may be provided at the computing-based device to enable application software to be executed on the device. Depending on the functionality and capabilities of the computing device 1300 and application of the computing device, software and/or computer executable instructions may include functionality to perform the methods of Figure 12.

For example, the computing device 1300 may be used to implement the second node 120 and may include software and/or computer executable

instructions that may include functionality to perform the methods of Figure 12.

The software and/or computer executable instructions may be provided using any computer-readable media that is accessible by computing based device 1300. Computer-readable media may include, for example, computer storage media such as memory 1304 and communications media. Computer storage media, such as memory 1304, includes volatile and non-volatile, removable and non-removable media implemented in any method or technology. A data store 1304A of the memory 1304 is configured for storage of information such as computer readable instructions, data structures, program modules or other data.

Computer storage media may include, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other non-transmission medium that can be used to store information for access by a computing device. In contrast, communication media may embody computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave, or other transport mechanism. As defined herein, computer storage media does not include communication media. Although the computer storage media, such as the memory 1304, is shown within the computing-based device 1300 it will be appreciated that the storage may be distributed or located remotely and accessed via a network or other communication link, e.g. using communication interface 1306.

The computing-based device 1300 may also optionally or if desired comprises an input/output controller 1315 arranged to output display information to a display device 1312 which may be separate from or integral to the computing-based device 1300. The display information may provide a graphical user interface. The input/output controller 1315 is also arranged to receive and process input from one or more devices, such as a user input device 1314, e.g. a mouse or a keyboard. This user input may be used to set scheduling for measurement reports, or for allocating communication resources, or to set which communications resources are of a first type and/or of a second type etc. In an embodiment the display device 1312 may also act as the user input device 1314 if it is a touch sensitive display device. The input/output controller 1315 may also output data to devices other than the display device, e.g. other computing devices via communication interface 1306, any other communication interface, or a locally connected printing device/computing devices etc.

Figure 13b illustrates a schematic block diagram of the second node 120 according to another embodiment. The second node 120 comprises a receiving module 1310, a decoding module 1320, a re-transmitting module 1330, a receiving module 1340, and a transmitting module 1350, which are configured to perform the steps performed by the second node 120 according to Figure 12.

In view of the above, the second node 120 provides the following embodiments. The second node 120 is configured for managing an ACK/NACK-message of a HARQ process relating to a set of transport blocks received by a first

node 110 from a second node 120.

As mentioned, each transport block of the set of transport blocks comprises a set of code block groups. Each code block group comprises a set of code blocks,

The second node 120 and/or the processor 1302 and/or the receiving module 1310 may be configured to receive a configuration from the first node 110, wherein the configuration relates to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group

The second node 120 and/or the processor 1302 and/or the receiving module 1310 is configured to receive the ACK/NACK-message from the first node 110.

The second node 120 and/or the processor 1302 and/or the decoding module 1320 is configured to decode bits of the ACK/NACK-message to find one or more sets of code blocks to be re-transmitted. Each set of code blocks is indicated by a respective bit that is cleared. Said respective bit is taken in order from the bits of the ACK/NACK-message according to a tree structure derived from a binary search used when encoding the ACK/NACK-message.

In some embodiments, the second node 120 and/or the processor 1302 and/or the decoding module 1320 may be configured to decode bits of the ACK/NACK-message by taking the bits in order according to the tree structure based on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group

According to the line-embodiments, the second node 120 and/or the processor 1302 and/or the decoding module 1320 may be configured to decode the bits of the ACK/NACK-message while taking into account that said respective bits are included into the ACK/NACK-message line by line from the tree structure.

According to the branch-embodiments, the second node 120 and/or the processor 1302 and/or the decoding module 1320 may be configured to decode the bits of the ACK/NACK-message while taking into account that said respective bits are included into the ACK/NACK-message branch by branch from the tree structure.

In some embodiments, the second node 120 and/or the processor 1302 and/or the decoding module 1320 may be configured to decode the bits of the ACK/NACK-message while taking into account that the ACK/NACK-message comprises a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block.

According to the indicator-embodiments, the second node 120 and/or the processor 1302 and/or the decoding module 1320 may be configured to decode bits of the ACK/NACK-message by decoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective

range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation according to Eq.1.

According to some examples of the indicator-embodiments, each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one.

According to some examples of the indicator-embodiments, a first indicator of the set of indicators may be preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

According to some examples of the indicator-embodiments, the set of indicators consists of one indicator, i.e. a length of the set of indicators is equal to one. This means that the set of indicators comprises only one indicator.

The second node 120 and/or the processor 1302 and/or the re-transmitting module 1330 may be configured to re-transmit said one or more sets of code blocks to the first node 110.

The term 'computer' is used herein to refer to any device with processing capability such that it can execute instructions. Those skilled in the art will realise that such processing capabilities are incorporated into many different devices and therefore the term 'computer' or 'computing device' includes PCs, servers, base stations, eNBs, network nodes and other network elements, mobile telephones, UEs, personal digital assistants, other portable wireless communications devices and many other devices.

Those skilled in the art will realise that storage devices utilised to store program instructions can be distributed across a network. For example, a remote computer may store an example of the process described as software. A local or terminal computer may access the remote computer and download a part or all of the software to run the program.

Alternatively, the local computer may download pieces of the software as needed, or execute some software instructions at the local terminal and some at the remote computer (or computer network). Those skilled in the art will also realise that by utilising conventional techniques known to those skilled in the art that all, or a portion of the software instructions may be carried out by a dedicated circuit, such as a DSP, programmable logic array, or the like.

Any range or device value given herein may be extended or altered without losing the effect sought, as will be apparent to the skilled person.

It will be understood that the benefits and advantages described above may relate to one example or embodiment or may relate to several examples or embodiments. The examples or embodiments are not limited to those that solve any or all of the stated problems or those that have any or all of the stated benefits and advantages.

Any reference to 'an' item refers to one or more of those items. The term 'comprising' is used herein to mean including the method blocks, features or elements identified, but that such blocks, features or elements do not comprise an

exclusive list and a method or apparatus may contain additional blocks, features or elements.

The steps of the methods described herein may be carried out in any suitable order, or simultaneously where appropriate. Additionally, individual blocks may be deleted from any of the methods without departing from the spirit and scope of the subject matter described herein. Aspects of any of the examples described above may be combined with aspects of any of the other examples described to form further examples without losing the effect sought.

It will be understood that the above description of a preferred embodiment is given by way of example only and that various modifications may be made by those skilled in the art. Although various embodiments have been described above with a certain degree of particularity, or with reference to one or more individual embodiments, those skilled in the art could make numerous alterations to the disclosed embodiments without departing from the spirit or scope of this disclosure.

## Claims

1. A method for providing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQquest, "HARQ", process relating to a set of transport blocks received by a first node, wherein each transport block of the set of transport blocks comprises a set of a code block groups, wherein each code block group comprises a set of code blocks, wherein the method, performed by the first node, comprises:

generating an ACK/NACK message for transmission by the first node by encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation:

$$2^n \geq \frac{a(a+1)}{2}$$

2. The method as claimed in claim 1, wherein the encoding of the set of indicators to generate the ACK/NACK-message comprises including said bits of those indicators in order into the ACK/NACK-message while taking into account at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group.

3. The method as claimed in claim 2, wherein encoding comprises encoding a respective transport block bit indicating with zero or one, respectively, whether or not to retransmit at least one code block of each respective transport block of the set of transport blocks.

4. The method as claimed in claim 1, wherein each indicator of the set may be preceded by a zero and a last one of the indicators of the set is directly followed by a one.

5. The method as claimed in claim 1, wherein a first indicator of the set is preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

6. The method as claimed in claim 1, wherein the set of indicators consists of one indicator.

7. A method for managing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQquest, "HARQ", process relating to a set of transport blocks received by a first node (110) from a second node (120), wherein each transport block of the set of transport blocks comprises a set of code block groups, wherein each code block group comprises a set of code blocks, wherein the method, performed by the second node (120), comprises:

decoding of the ACK/NACK message comprises decoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted

and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation:

$$2^n \geq \frac{a(a+1)}{2} \quad (\text{Eq.1})$$

wherein  $a$  represents number of code blocks of each transport block.

8. The method as claimed in claim 7, wherein each indicator of the set is preceded by a zero and a last one of the indicators of the set is directly followed by a one.

9. The method as claimed in claim 7, wherein a first indicator of the set is preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

10. The method as claimed in claim 7, wherein the set of indicators consists of one indicator.

11. A method for providing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQuest, "HARQ", process relating to a set of transport blocks received by a first node (110), wherein each transport block of the set of transport blocks comprises a set of code block groups, wherein each code block group comprises a set of code blocks, wherein the method, performed by the first node (110), comprises:

encoding (S060) bits for the ACK/NACK-message by use of a binary search to indicate one or more sets of code blocks to be re-transmitted, wherein each set of code blocks to be re-transmitted is indicated by a respective bit that is cleared, wherein said respective bit is included in the ACK/NACK-message in order according to the binary search, and

terminating (S070) the encoding (S060) of the bits for the ACK/NACK message by use of the binary search when

- said each set of code blocks consists of one code block, or
- a number of bits, included in the ACK/NACK-message, has reached a predetermined number of bits.

12. The method as claimed in claim 11, further comprising:

transmitting (S080) the ACK/NACK-message to a second node (120), wherein the second node (120) transmitted the set of transport blocks.

13. The method as claimed in claim 11 or 12, wherein the encoding (S060) of bits of the ACK/NACK-message comprises including said respective bits in order into the ACK/NACK-message while taking into account on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group.

14. The method as claimed in any of claims 11 to 13, wherein the method comprises: determining (S010) a configuration relating to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups

of each transport block and the number of code blocks of each code block group, and transmitting (S020) the configuration to the second node (120).

15. The method as claimed in any of claims 11 to 13, wherein said respective bits are included into the ACK/NACK-message line by line from a tree structure obtained by the binary search.

16. The method as claimed in any one of claims 11 to 14, wherein said respective bits are included into the ACK/NACK-message branch by branch from a tree structure obtained by the binary search.

17. The method as claims in any one of claims 13-16, wherein encoding of the ACK/NACK-message comprises encoding a respective transport block bit indicating with zero or one, respectively, whether or not to retransmit at least one code block of each respective transport block of the set of transport blocks.

18. The method as claimed in claim 17, wherein the encoding of the ACK/NACK message comprises encoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation:

$$2^n \geq \frac{a(a+1)}{2}$$

wherein  $a$  represents number of code blocks of each transport block.

19. The method as claimed in claim 18, wherein each indicator of the set is preceded by a zero and a last one of the indicators of the set is directly followed by a one.

20. The method as claimed in claim 18, wherein a first indicator of the set is preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a positive integer greater than one.

21. The method as claimed in claim 18, wherein the set of indicators consists of one indicator.

22. A method for managing an acknowledgment/non-acknowledgment message, "ACK/NACK-message" of a Hybrid Automatic Repeat reQuest, "HARQ", process relating to a set of transport blocks received by a first node (110) from a second node (120), wherein each transport block of the set of transport blocks comprises a set of code block groups, wherein each code block group comprises a set of code blocks, wherein the method, performed by the second node (120), comprises:

receiving (S090) the ACK/NACK-message from the first node (110), and decoding (S100) bits of the ACK/NACK-message to find one or more sets of code blocks to be re-transmitted, wherein each set of code blocks is indicated

by a respective bit that is cleared, wherein said respective bit is taken in order from the bits of the ACK/NACK-message according to a tree structure derived from a binary search used when encoding the ACK/NACK-message.

23. The method as claimed in claim 22, further comprising:  
re-transmitting (S110) said one or more sets of code blocks to the first node (110)

24. The method as claimed in any one of claims 22-23, wherein the decoding (S100) of bits of the ACK/NACK-message comprises taking the bits in order according to the tree structure based on at least one of:

- a number of transport blocks of each ACK/NACK-message,
- a number of code block groups of each transport block, and
- a number of code blocks of each code block group.

25. The method as claimed any of claims 22 to 24, wherein the method comprises:  
receiving (S030) a configuration from the first node (110), wherein the configuration relates to at least one of the number of transport blocks of each ACK/NACK-message, the number of code block groups of each transport block and the number of code blocks of each code block group.

26. The method as claimed in any one of claims 22-25, wherein the decoding (S100) takes into account that said respective bits are included into the ACK/NACK message line by line from the tree structure.

27. The method as claimed in any one of claims 22-25, wherein the decoding takes into account that said respective bits are included into the ACK/NACK-message branch by branch from the tree structure.

28. The method as claims in any one of claims 22-27, wherein the decoding takes into account that the ACK/NACK-message comprises a respective transport block bit indicating with zero or one, respectively, whether or not to re-transmit at least one code block of each respective transport block.

29. The method as claimed in claim 28, wherein the decoding of the ACK/NACK message comprises decoding a set of indicators indicating a respective starting position of one or more code block to be re-transmitted and a respective range for indicating said one or more code blocks to be re-transmitted, wherein each indicator of the set comprises  $n$  bits, wherein  $n$  is a least integer that fulfils the relation:

$$2^n \geq \frac{a(a+1)}{2}$$

wherein  $a$  represents number of code blocks of each transport block.

30. The method as claimed in claim 29, wherein each indicator of the set is preceded by a zero and a last one of the indicators of the set is directly followed by a one.

31. The method as claimed in claim 29, wherein a first indicator of the set is preceded by  $n$  bits representing a number of indicators of the set, wherein  $n$  is a

positive integer greater than one.

32. The method as claimed in claim 29, wherein the set of indicators consists of one indicator.

33. A computer readable medium comprising program code stored thereon, which when executed on a processor, causes the processor to perform a method according to any one of claims 1-32.

34. A non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to any one of claims 1-32.

35. The non-transitory computer readable medium of claim 34 comprising at least one of: a hard disk, a Compact Disc, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, an Electrically Erasable Programmable Read Only Memory and a Flash memory and a Solid State Drive.

36. A first node (110) comprising a processor unit, a storage unit and a communications interface, wherein the processor unit, the storage unit, and the communications interface are configured to perform a method as claimed in any one of claims 1-6.

37. A second node (120) comprising a processor unit, a storage unit and a communications interface, wherein the processor unit, the storage unit, and the communications interface are configured to perform a method as claimed in any one of claims 7-10.

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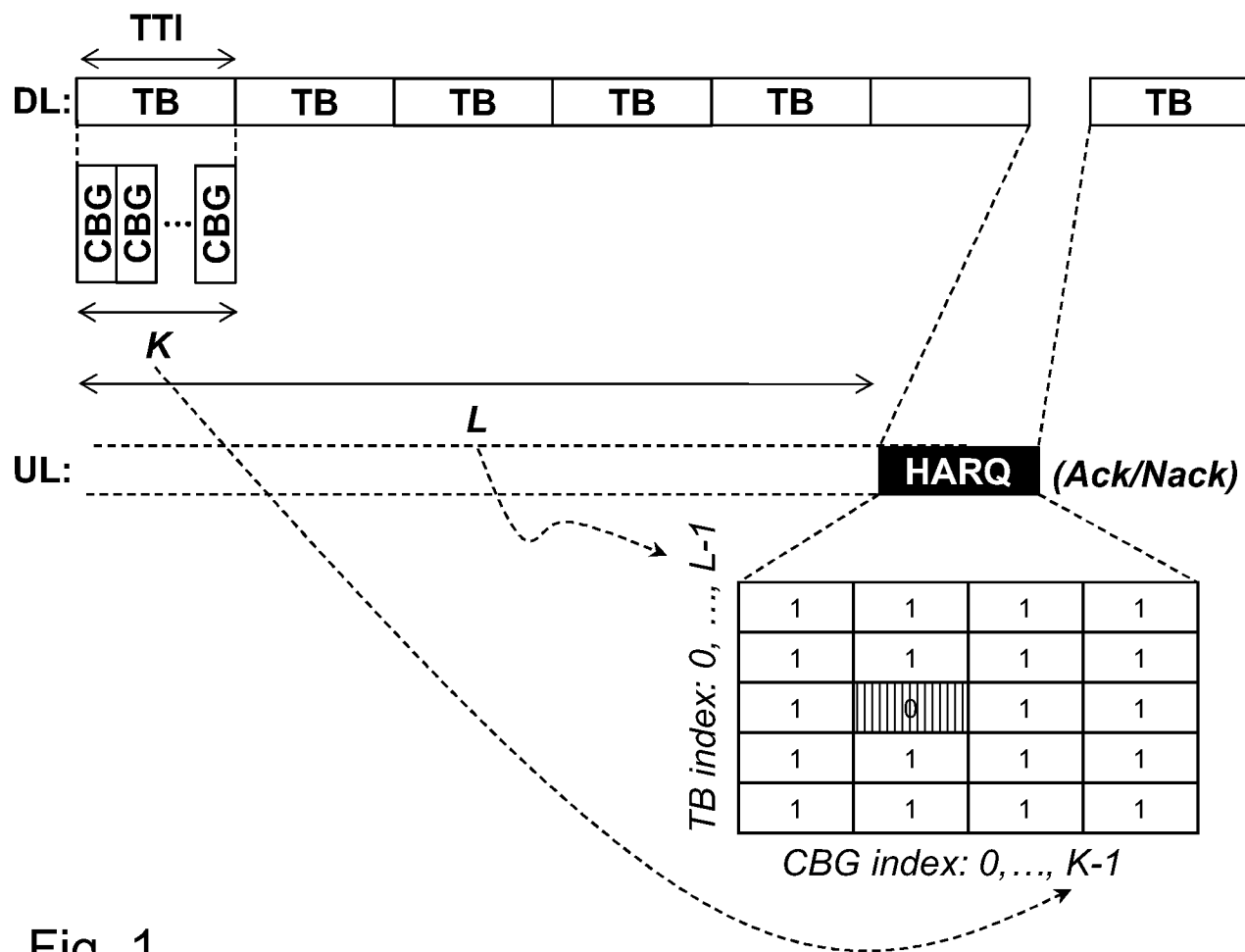


Fig. 1

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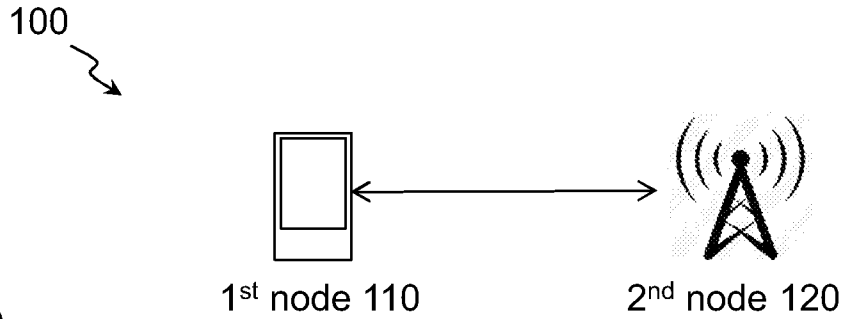


Fig. 2

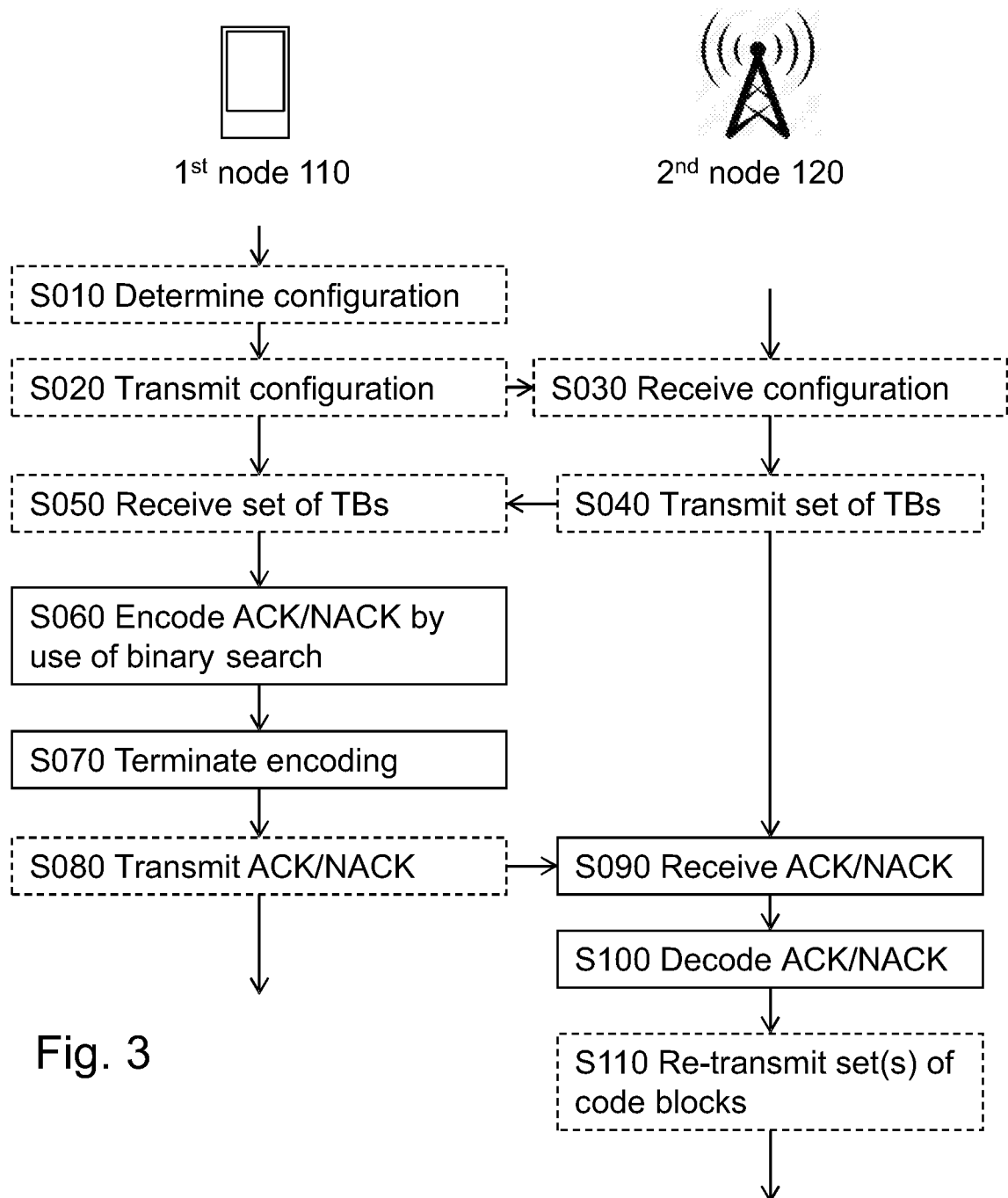


Fig. 3

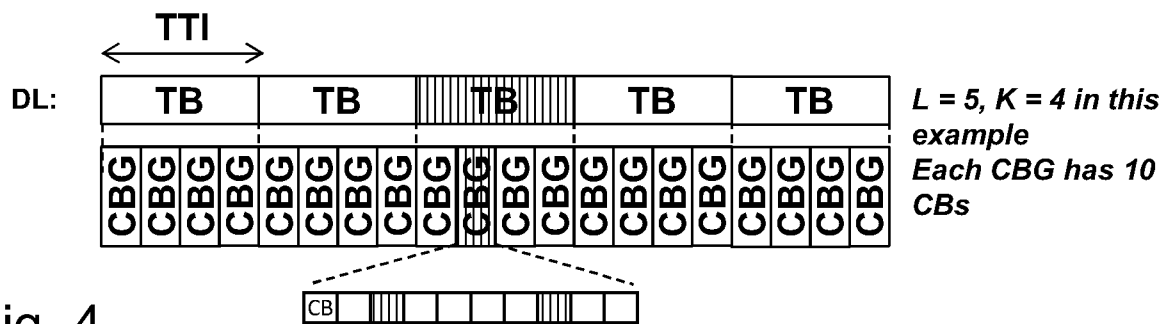


Fig. 4

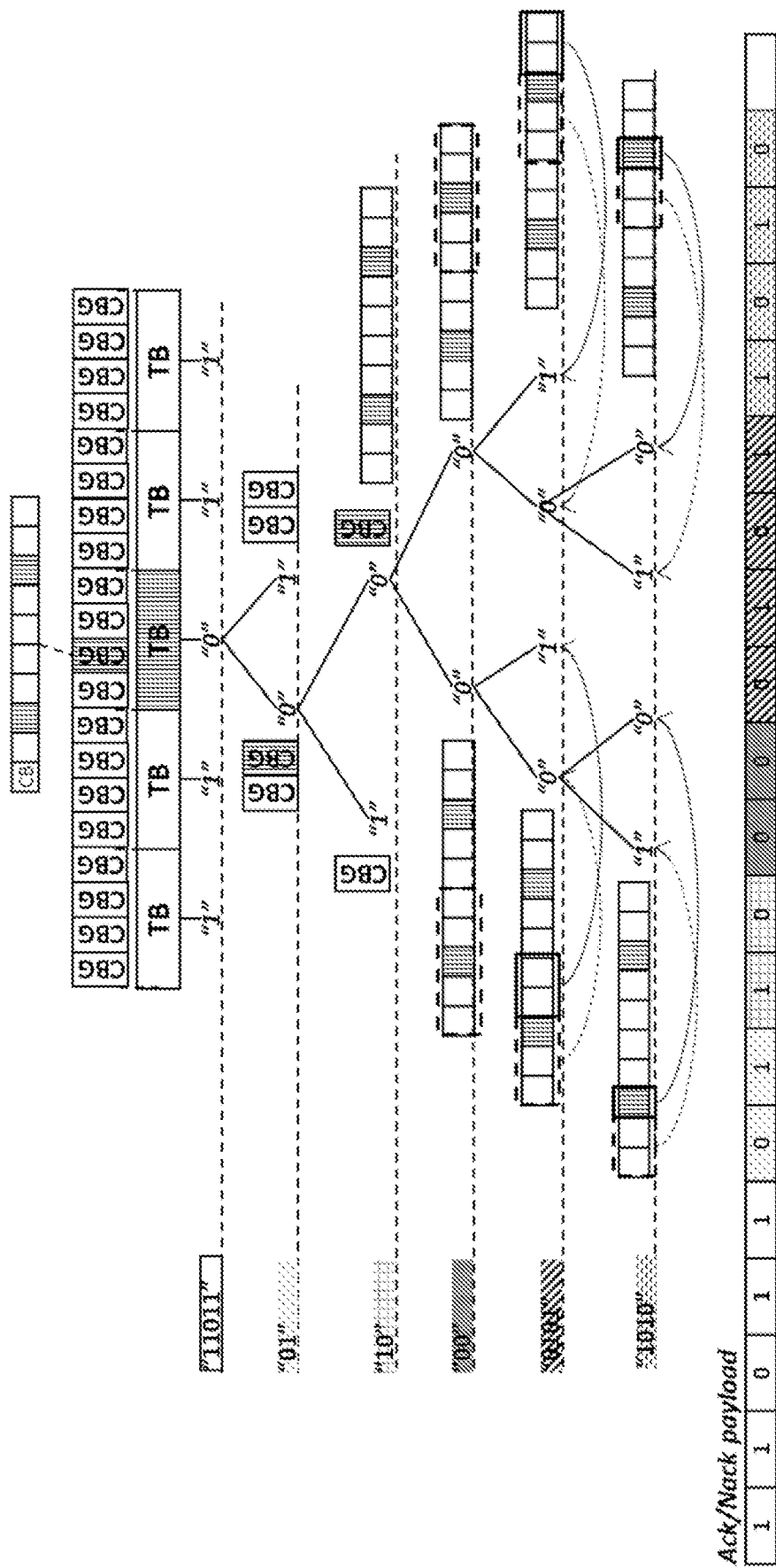


Fig. 5

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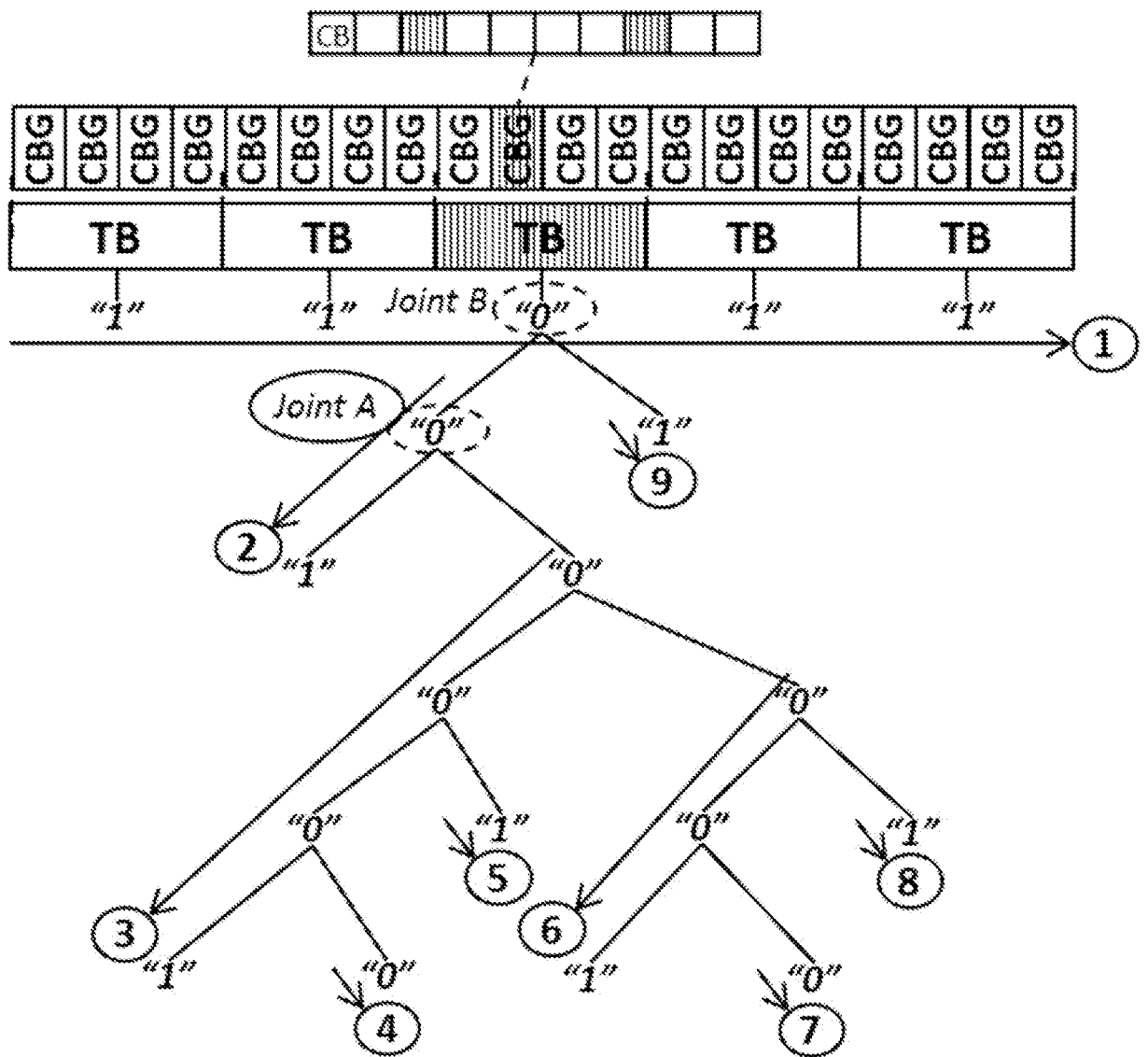
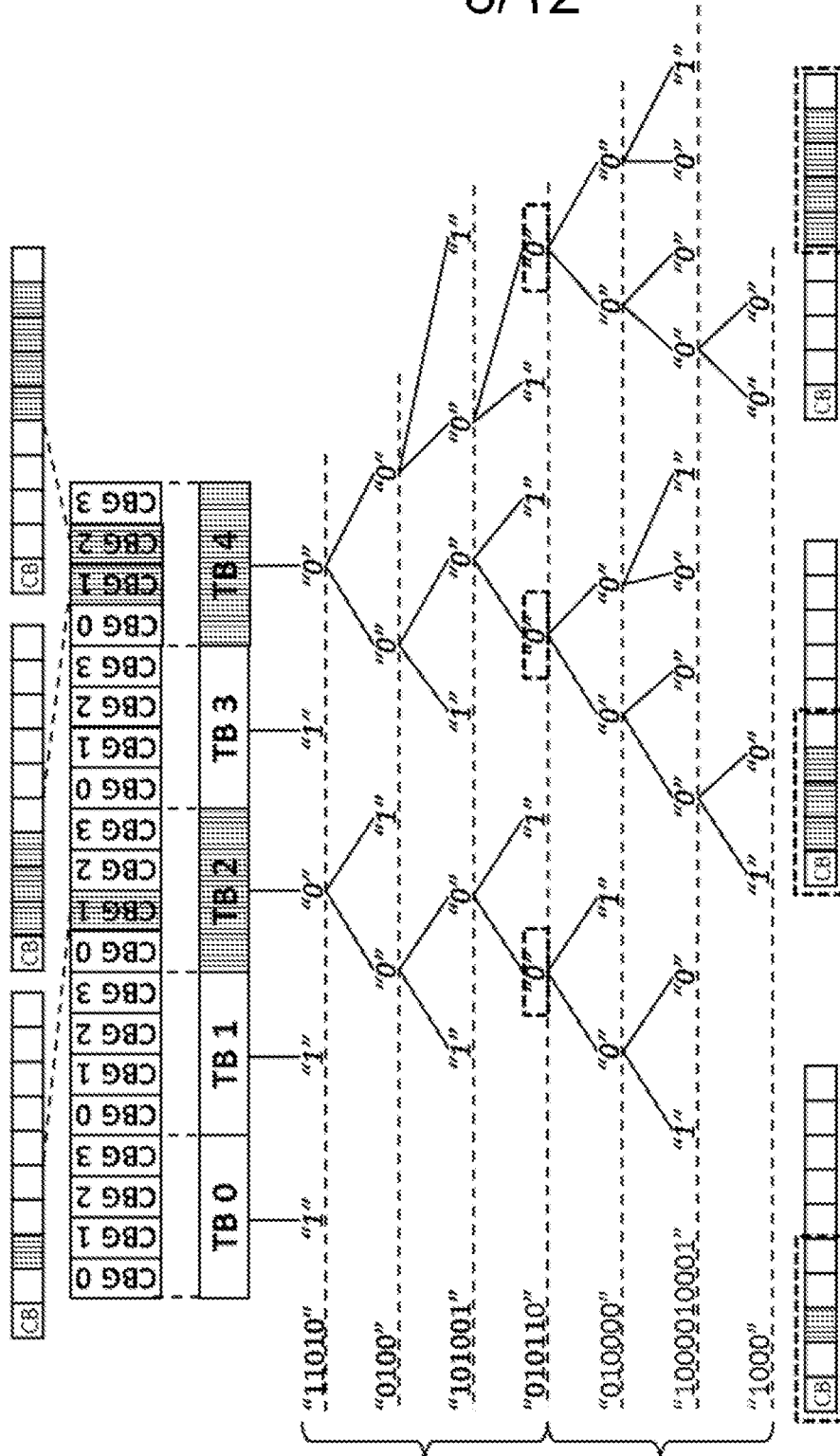


Fig. 6

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Ack/Nack bits are collected line by line.

**Bold** bits are within the size limit and will be transmitted.

*Others will be discarded and assumed all "0" by the gNB.*

Fig. 7



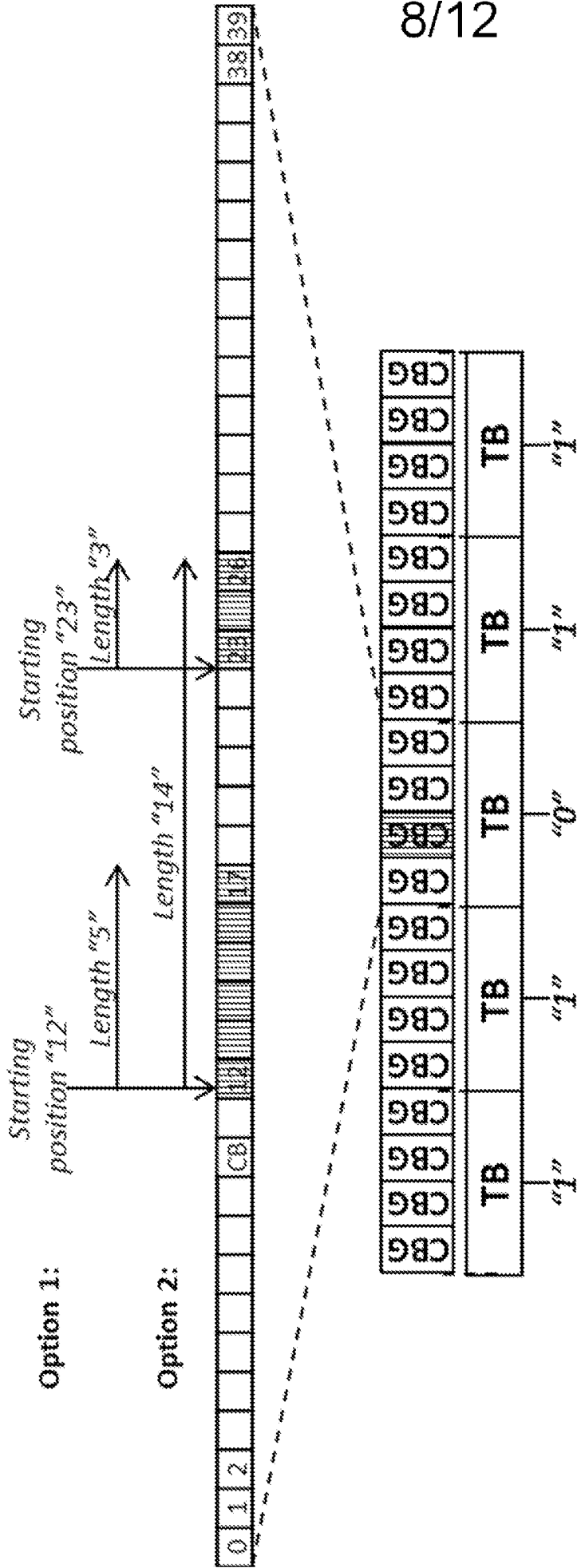


Fig. 9

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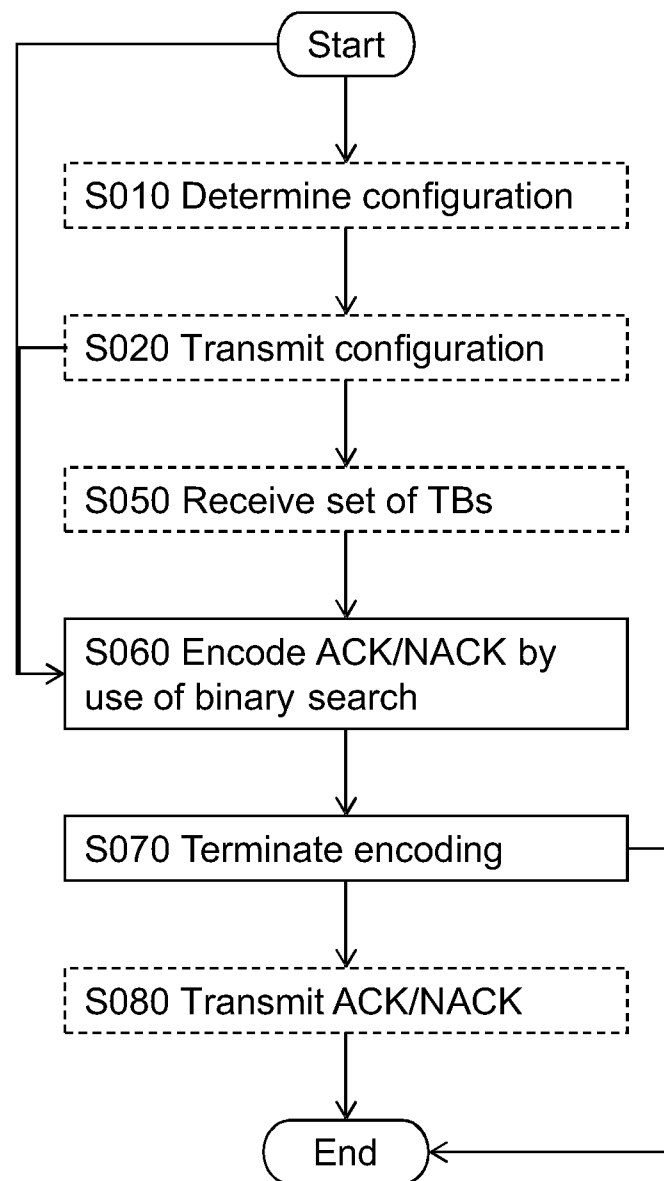


Fig. 10

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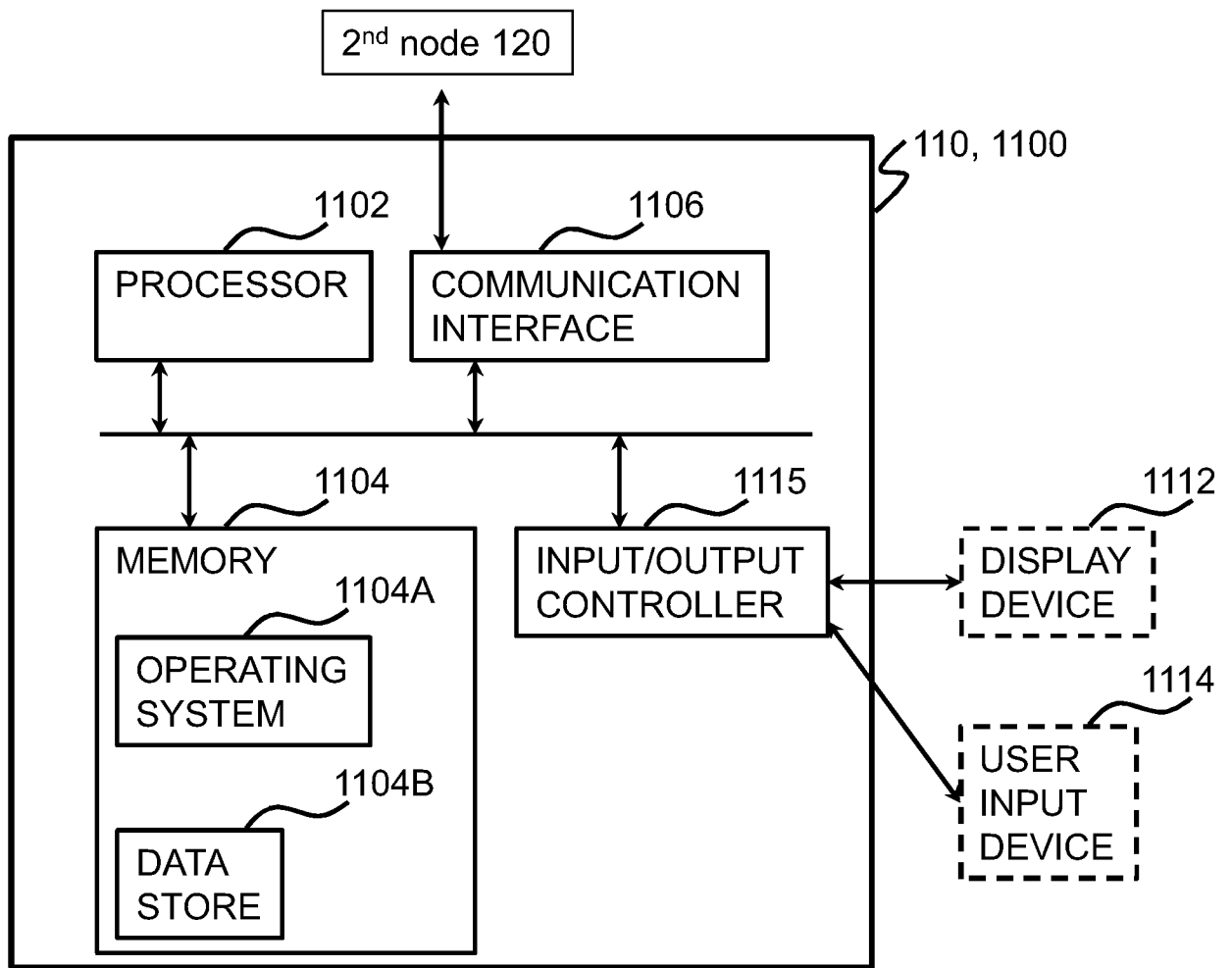


Fig. 11a

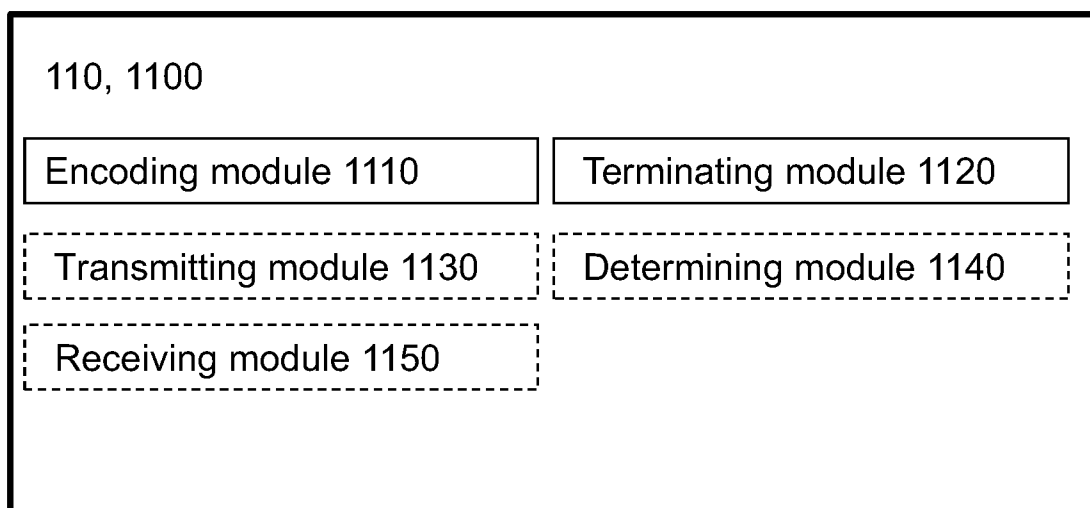


Fig. 11b

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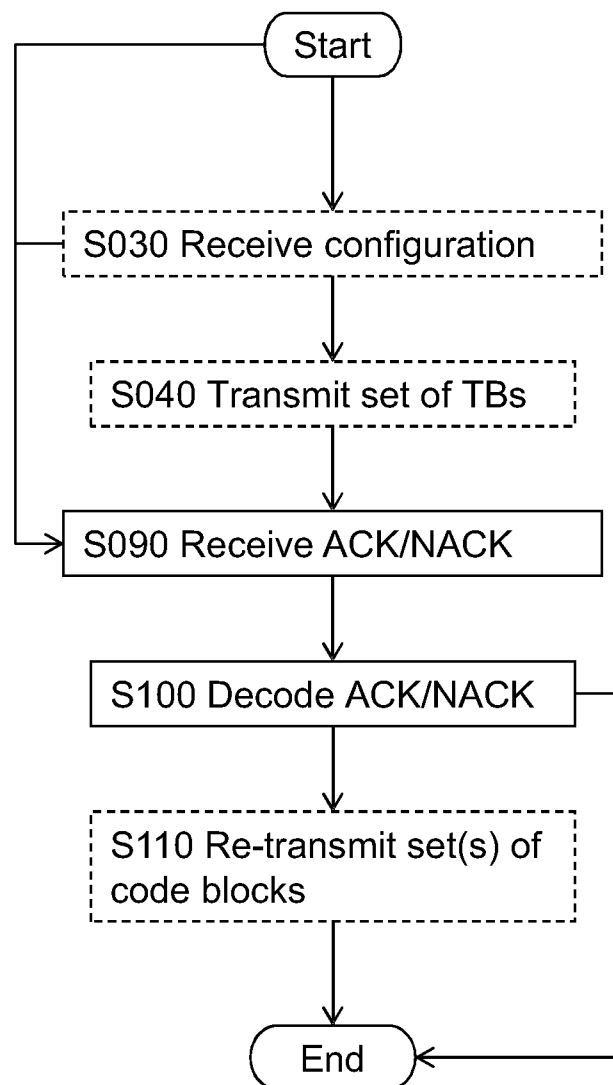


Fig. 12

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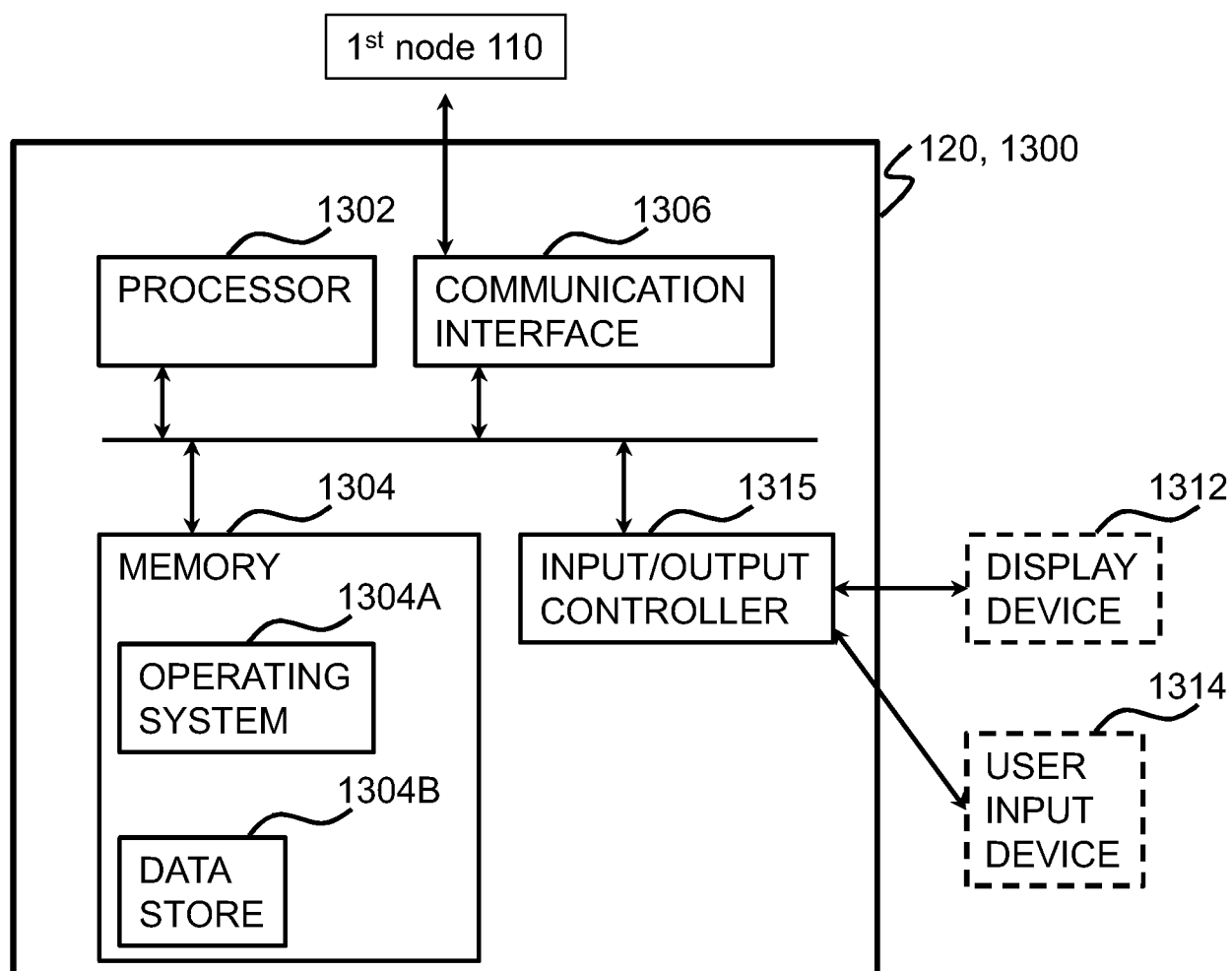


Fig. 13a

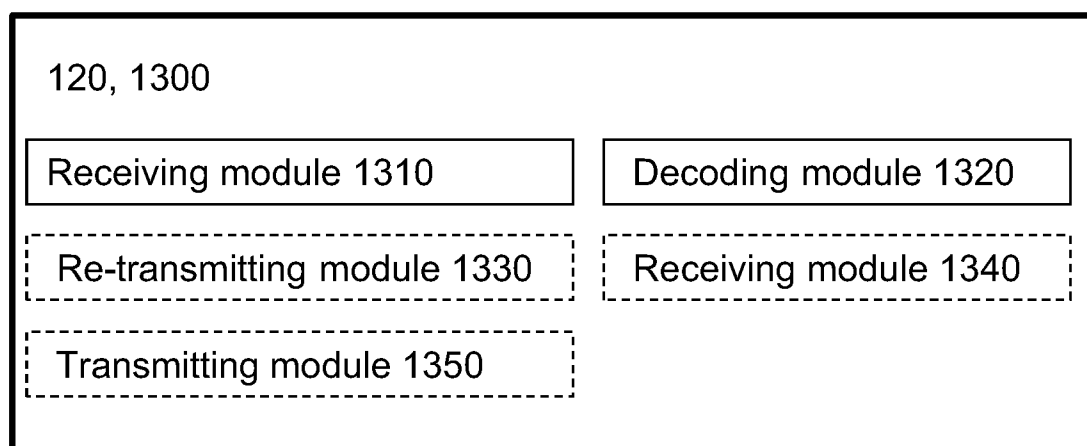


Fig. 13b

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2018/085218

**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

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)

CNABS; CNTXT; CNKI; VEN; WOTXT; EPTXT; USTXT; 3GPP: HARQ, ACK, NACK, code w block?, set, group, CBG, CB, TB, level, based, binary, tree

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                          | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | WO 2016126653 A1 (QUALCOMM INC.) 11 August 2016 (2016-08-11)<br>the whole document                                                                          | 1-37                  |
| A         | CN 104301077 A (POTEVIO INST TECHNOLOGY CO., LTD.) 21 January 2015<br>(2015-01-21)<br>the whole document                                                    | 1-37                  |
| A         | US 8730889 B2 (LG ELECTRONICS INC.) 20 May 2014 (2014-05-20)<br>the whole document                                                                          | 1-37                  |
| A         | CN 105515733 A (ZTE CORP.) 20 April 2016 (2016-04-20)<br>the whole document                                                                                 | 1-37                  |
| A         | Qualcomm Incorporated. "Use cases of multi-bit HARQ-ACK feedback"<br>3GPP TSG-RAN WG1 #88bis, R1-1705619, 25 March 2017 (2017-03-25),<br>the whole document | 1-37                  |

☐ Further documents are listed in the continuation of Box C.☒ 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

11 July 2018

Date of mailing of the international search report

19 July 2018

Name and mailing address of the ISA/CN

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**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/CN2018/085218**

| Patent document<br>cited in search report |            |    | Publication date<br>(day/month/year) | Patent family member(s) |              |    | Publication date<br>(day/month/year) |
|-------------------------------------------|------------|----|--------------------------------------|-------------------------|--------------|----|--------------------------------------|
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|                                           |            |    |                                      | BR                      | 112017016848 | A2 | 27 March 2018                        |
|                                           |            |    |                                      | JP                      | 2018509814   | A  | 05 April 2018                        |
|                                           |            |    |                                      | KR                      | 20170115049  | A  | 16 October 2017                      |
|                                           |            |    |                                      | EP                      | 3254392      | A1 | 13 December 2017                     |
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| US                                        | 8730889    | B2 | 20 May 2014                          | KR                      | 20100048865  | A  | 11 May 2010                          |
|                                           |            |    |                                      | KR                      | 101648775    | B1 | 17 August 2016                       |
|                                           |            |    |                                      | US                      | 2011205996   | A1 | 25 August 2011                       |
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|                                           |            |    |                                      | WO                      | 2010050688   | A3 | 08 July 2010                         |
| CN                                        | 105515733  | A  | 20 April 2016                        | WO                      | 2015184919   | A1 | 10 December 2015                     |
|                                           |            |    |                                      | EP                      | 3200376      | A4 | 31 January 2018                      |
|                                           |            |    |                                      | EP                      | 3200376      | A1 | 02 August 2017                       |
|                                           |            |    |                                      | US                      | 2017303284   | A1 | 19 October 2017                      |