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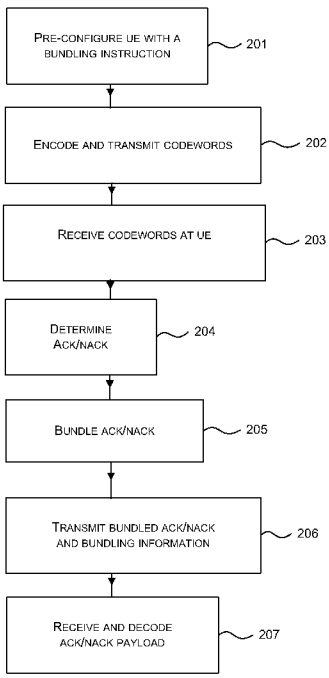


FIGURE 2

(57) Abstract: A method for dynamic ACK/NACK bundling includes generating and transmitting an ACK/NACK bundling instruction from a base station to a User Equipment. The instruction can contain information on a preferred type of bundling (spatial, time, frequency/cell). The User Equipment generates an ACK/NACK response in respect of received codewords and based on information contained in the received bundling instruction, bundles a plurality of ACK/NACK responses together to generate an ACK/NACK payload of minimal size. The User Equipment sends bundling information along with the ACK/NACK payload to the base station, the bundling information enabling the base station to determine the HARQ-ACK codebook size and decode the ACK/NACK payload.

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ACK/NACK bundling in Wireless Communication Systems

Technical Field

Embodiments of the present invention generally relate to wireless communication systems and in particular to devices and methods for implementing a Hybrid Automatic Repeat Request process with ACK/NACK bundling.

Background

Wireless communication systems, such as the third-generation (3G) of mobile telephone standards and technology are well known. Such 3G standards and technology have been developed by the Third Generation Partnership Project (3GPP). The 3rd generation of wireless communications has generally been developed to support macro-cell mobile phone communications. Communication systems and networks have developed towards a broadband and mobile system. The 3rd Generation Partnership Project has developed the so-called Long Term Evolution (LTE) system, namely, an Evolved Universal Mobile Telecommunication System Territorial Radio Access Network, (E-UTRAN), for a mobile access network where a macrocell is supported by a base station known as an eNodeB or eNB (evolved NodeB). More recently, LTE is evolving further towards the so-called 5G or NR (new radio) systems where a cell is supported by a base station known as a gNB.

In LTE networks, a Hybrid Automatic Repeat Request (HARQ) mechanism is implemented in order to correct erroneous packets (transport blocks) in the PHY layer. Multiple HARQ processes exist for a transmitting device to send transport blocks to a receiving device. Once a transport block is sent from a particular process, it waits for receipt of an ACK/NACK (acknowledged or not acknowledged) bit. Until the transmitting device receives an ACK/NACK, the process will be in an inactive state and will not process other transport blocks. The transmitting device buffers the transmitted transport blocks of the multiple processes so it may retransmit in the case of receipt of a NACK until an ACK is received. This is the well-known stop-and-wait protocol with multiple parallel processes. It is possible to ACK/NACK a number of transport blocks from one cell or multiple cells together within one ACK/NACK transmission. HARQ-ACK/NACK information comprising multiple bits is typically associated with a HARQ-ACK/NACK codebook.

In a known downlink HARQ process in LTE, downlink data is sent from a base station (an eNB) to a wireless communication device (or User Equipment) via the PDSCH (Physical Downlink Shared Channel). Then, ACK/NACK information is sent from the UE to the eNB either through the PUCCH (Physical Uplink Control Channel) or the PUSCH (Physical Uplink Shared Channel). If, following a NACK, data needs to be re-sent, then it is re-sent from the eNB to the UE via the PDSCH (Physical Downlink

Shared Channel). In LTE, HARQ ACK/NACK is carried by uplink control information (UCI). The ACK/NACK payload can be a drain on available resources and therefore any means to reduce the ACK/NACK payload/codebook size (and effectively, the UCI payload), particularly on the uplink (from the UE to an eNB), without detriment to the HARQ process would be beneficial.

A known way of reducing the ACK/NACK payload relies on bundling several ACK/NACK bits together (in a binary AND operation), each bit corresponding to a downlink codeword, (where a codeword is an encoded transport block) and transmitting (from the UE to the eNB) a single bit instead. Bundling can be performed in several dimensions. For example, "spatial bundling" can be done in cases where the available transmission modes support multiple codewords per subframe by a transmitter; "time bundling" can be done to ACK/NACK multiple subframes together for a transmitter; "cell bundling" (or frequency bundling) can be done to bundle ACK/NACK bits across synchronised cells per TTI (Transmission Time Interval).

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 a first aspect of the present invention there is provided a method for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the method comprising: in a wireless communication unit; generating and transmitting an ACK/NACK bundling instruction; in a wireless communication device, receiving the transmitted ACK/NACK bundling instruction, receiving one or more codewords transmitted by one or more wireless communication elements, generating a ACK/NACK response in respect of each received codeword, bundling a plurality of generated ACK/NACK responses based on the received bundling instruction to generate an ACK/NACK payload, transmitting the ACK/NACK payload and transmitting bundling information relating to properties of the generated ACK/NACK payload; and at the wireless communication unit, receiving the ACK/NACK payload and bundling information, and decoding the ACK/NACK payload based on the received bundling information.

The wireless communication unit may be arranged to configure the bundling instruction based on ACK/NACK statistics (i.e. previously received ACK/NACK responses from one or several wireless communication devices), available Control channel resources, whether a wireless communication device is power limited, total CSI (Channel State Information) payload, whether a conventional ACK/NACK feedback size exceeds a specified limit, the throughput requirements of a

communications link between the wireless communication unit and the wireless communication device, and/or other network constraints.

The bundling instruction may contain information relating to one of the following: whether or not to bundle ACK/NACK responses; allowable bundling modes (i.e. in which dimensions bundling can be done; e.g. spatial, time, cell/frequency; how many errors (if any) are allowed while bundling. An example of a bundling error may be that a device generates an ACK response in respect to a particular, received codeword but generates a NACK response for the bundle of codewords including this particular codeword. In NR systems, there is the possibility of allowing multiple ACK/NACK bits per Transport Block so this may constitute another bundling mode for such systems.

The wireless communication device may be configured to use the received bundling instruction to determine the smallest sized ACK/NACK payload by examining different bundling combinations (modes) permitted by the bundling instruction. For example in some instances the use of just time bundling may provide the smallest sized payload which has no more than the permitted number of errors. In other instances, it may be more beneficial to combine time bundling together with frequency bundling. The wireless communication device may be configured to also consider which subframes are associated with bundled ACK/NACK responses and/or which Component Carriers are associated with bundled ACK/NACK responses.

The bundling information may comprise one or more of the following: whether or not the ACK/NACK payload is bundled; the bundling mode used; which subframes are associated with bundled ACK/NACK responses; which Component Carriers are associated with bundled ACK/NACK responses, identities of Transport Blocks associated with bundled ACK/NACK responses.

In one embodiment, the bundling instruction includes an indication of what information is to be included in the bundling information.

The wireless communication system may be an LTE system or 5G/NR system.

In one embodiment, the wireless communication unit is a base station, for example an eNB, and the wireless communication device is a User Equipment. The User Equipment may receive codewords from several eNBs in the wireless communication system or just from the eNB which transmits the bundling instruction. In this embodiment, a downlink HARQ process may be implemented.

In another embodiment, the wireless communication unit is a User Equipment and the wireless communication device is a base station. The base station may receive codewords from several User Equipments or just from the User Equipment which

transmits the bundling instruction. In this embodiment, an uplink HARQ process may be implemented.

The invention provides a dynamic bundling approach to reducing ACK/NACK overheads. In a preferred embodiment, a base station may signal to a UE, limitations on bundling and then the UE may decide if and how to bundle. In general, a base station has a better view of the expected throughput loss from each type of bundling, the desired PUCCH or PUSCH resource overhead and the CSI payload requirements. On the other hand, a UE knows its current power limitations and the exact ACK/NACK feedback. The invention exploits these contrasting capabilities of base station and UE. The invention also provides a mechanism for a base station (eNB for example) and a UE to have a common understanding of the ACK/NACK codebook size. This is implicit in the bundling information that a UE may send to a base station together with the ACK/NACK bits comprising the ACK/NACK payload. At the base station, by decoding the bundling information first, the base station can know the codebook size. Herein, the (modified) ACK/NACK codebook comprises the ACK/NACK payload (i.e. bundled responses) preceded by the bundling information.

In one embodiment, the ACK/NACK codebook has a size chosen from a set of predetermined fixed sizes and the codebook is decoded by blind decoding based on knowledge of the predetermined fixed sizes.

Advantageously, the invention provides an ACK/NACK payload compression gain and reduces downlink throughput loss compared with known (non-dynamic) bundling techniques.

According to a second aspect of the invention there is provided a wireless communication unit for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the wireless communication unit including a processing unit arranged to generate an ACK/NACK bundling instruction, and wherein the wireless communication unit is arranged to transmit, to a wireless communication device, the ACK/NACK bundling instruction; receive from the wireless communication device, an ACK/NACK payload, comprising an ACK/NACK response in respect of at least one codeword received by the wireless communication device, and bundling information relating to properties of the ACK/NACK payload; and wherein the processing unit is arranged to decode the ACK/NACK payload based on the received bundling information.

According to a third aspect of the invention, there is provided a wireless communication device for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the wireless communication device being arranged to; receive an ACK/NACK bundling instruction

and at least one codeword; and wherein the wireless communication device includes a processing device arranged to; generate an ACK/NACK response in respect of each received codeword, bundle a plurality of generated ACK/NACK responses based on the received bundling instruction to generate an ACK/NACK payload; and generate bundling information relating to properties of the ACK/NACK payload; and wherein the wireless communication device is arranged to transmit the ACK/NACK payload and bundling information.

In one embodiment, the processing device is arranged to calculate ACK/NACK payload sizes for a plurality of bundling modes and to select the bundling mode which provides the smallest ACK/NACK payload. A bundling mode may comprise for example; spatial bundling, time bundling, cell bundling or combinations of any of these three.

According to a fourth aspect of the invention, there is provided a non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to the first aspect.

The non-transitory computer readable medium may comprise at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

Brief description of the drawings

Further details, aspects and embodiments of the invention 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 simplified block diagram of a wireless communication system and operating in accordance with an example embodiment;

Figure 2 is a simplified flow chart illustrating an example of a method of ACK/NACK bundling;

Figure 3 illustrates an example of a modified ACK/NACK codebook: and

Figure 4 is a table showing examples of ACK/NACK codebook size modifications for various bundling options.

Detailed description of the preferred embodiments

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.

Figure 1 shows a wireless communication system 100 which may be an LTE system or some other system such as a 5G/NR system. The system 100 supports a HARQ process. System 100 may include a number of evolved Node Bs (eNB) or gNb 101 and other network entities (not shown). An eNB or gNB communicates with User Equipments (UEs) 102 and supports a respective cell 103. Each eNB/gNB performs the function (amongst others) of that of a base station and in general, each may support multiple cells. An eNB/gNB 101 is provided with a processing unit whose function will be described below. The UEs 102 may be dispersed throughout the system 100 and each UE may be stationary or mobile at any one time. A UE 102 may be for example, a cell phone, smart phone, wireless modem, laptop computer or other wireless communication device. The UE 102 is provided with a processing device 105 whose function will be described below. The system 100 supports HARQ processes on both the uplink (from a UE 102 to an eNB or gNB 101) and the downlink (from an eNB or gNB 101 to a UE 102). An uplink signal or channel can include data on the PUSCH control information on the PUCCH. In LTE in particular, the PUCCH carrying uplink control information (UCI) can include channel state information (CSI) reports, HARQ ACKnowledgement/NegativeAcknowledgement (ACK/NACK) and uplink scheduling requests (SR). A UE 102 can provide HARQ-ACK feedback for a PDSCH using a PUCCH. The UE feeds back ACK/NACK via the PUCCH to the eNB 101 regarding downlink data received via the PDSCH. The PUCCH can support multiple formats with various modulation and coding schemes as is usual for LTE systems.

An exemplary method for bundling ACK/NACK information in the wireless communication system 100 will now be described with reference to the flowchart of Figure 2. In this exemplary case of data transmission on the downlink, at 201, the processing unit 104 in the eNB/gNB 101 determines a bundling instruction and the eNB 101 pre-configures a UE 102 with the bundling instruction. In this example, the pre-configuring is done by sending the bundling instruction to the UE 102 via RRC signalling when a connection for the UE 102 is established or reconfigured. At 202, the eNB/gNB 101 encodes one or more codewords and transmits the codewords for reception by a UE 102. At 203, the UE 102 receives the multiple codewords in at least one downlink subframe from an eNB/gNB 101. At 204, the UE 102 decodes the received multiple codewords and determines an acknowledgement (ACK) or a negative acknowledgement (NACK) for each codeword based on a decoding result for the codeword. At 205, the processing device 105 in the UE 102 uses the received bundling instruction to bundle the ACK and NACK information for the multiple codewords to generate a bundled ACK/NACK payload. At 206, the UE 102 then sends the bundled ACK/NACK payload and bundling information relating to the ACK/NACK payload to the eNB/gNB 101. At 207, using the bundling information received, the eNB/gNB is able to determine the ACK/NACK codebook size and then decode the ACK/NACK information contained in the ACK/NACK payload.

In another example embodiment, an eNB 101 uses one bit (of a downlink transmission) to signal to a UE 102 if the dynamic bundling method of the present invention is to be used or alternatively, if a conventional semi-static method of bundling should be used instead. For example a bit set at a logical "0" denotes dynamic bundling and a bit set at a logical "1" denotes semi-static or non-dynamic bundling. In a further example, three bits (of a downlink transmission) can be used by an eNB 101 to signal to a UE 102 a type of bundling that it is allowed to use. For example, the three bits can be used to distinguish between spatial bundling, time bundling and cell (frequency) bundling.

In one example, the processing device 105 in the UE 102 modifies a conventional HARQ ACK/NACK codebook as follows. Extra (bundling) information is added to the conventional codebook and precedes the ACK/NACK responses. An example of a modified codebook is shown in Figure 3. A first portion 301 comprises the bundling information and precedes a second portion 302 which comprises the bundled ACK/NACK responses. The first portion 301 includes a first section 303 which contains information regarding whether dynamic bundling has been performed or not. A second section 304 contains information regarding a bundling mode, that is, the type of bundling which has been performed, e.g. spatial/subframe bundling, time bundling, cell (frequency) bundling. A third section 305 contains other information such as how many and which subframes are associated with bundled ACK/NACK responses or how many and which Component Carriers are associated with bundled ACK/NACK responses.

Based on what has been allowed by the eNB 101 (in the bundling instruction), the UE 102 can examine the possible bundling combinations and determine the optimal one. The table shown in Figure 4 illustrates the extra payload needed, apart from the dynamic bundling bit 303 shown in Figure 3, for various possible bundling combinations. In these examples of Figure 4, ACK/NACK is reported for N cells and in M subframes per cell (i.e. a bundling window of M subframes). It is assumed that the UE reports an extra N bits to denote in which cell, time bundling has been performed and an extra M bits to denote when, (that is, at which Time Transmission Interval), cell bundling has been used.

The amount of ACK/NACK payload compression may be modified by a variety of factors. For example, the eNB may allow the UE to include in the payload a certain number of errors due to the bundling process. The eNB may also give the UE a compression target and an indication of how many erroneous bits can be sent in an ACK/NACK codebook. The eNB may instruct the UE to keep the bundling information that it sends to a minimum number of bits (for example just a confirmation that bundling has been used but no indication of the mode) in order to achieve a high level of compression. Alternatively, the UE may be requested by the eNB to send a larger number of bits, for example, indicating the bundling mode and also information

relating to subframes and Component Carriers (such as the "other information" referred to in Figure 3) in order to achieve a moderate level of compression. Given particular values of N and M and a permissible number of bundling errors, the processing device 105 in the UE 102 calculates an ACK/NACK payload size for the various combinations of bundling modes (for example, spatial bundling only, spatial and time bundling, spatial and cell bundling, spatial, time and cell bundling) and selects the bundling mode having the lowest payload size for use in reporting ACK/NACK to the eNB.

When decoding, the eNB 102 has to know the exact size of the received ACK/NACK codebook in order to reconstruct the ACK/NACK bits 302 (see Figure 3). Typically, in an LTE system it can do this through rate unmatching and a channel decoding process. However, in order to do this, the eNB and UE have to have a common understanding of ACK/NACK payload within the UCI. One solution is to split the codebook into two portions. The first portion contains the information relating to the bundling process used by the UE (sections 303, 304 and 305 of Figure 3) and the second portion contains the rest of the payload (302 of Figure 3). Then the eNB can decode the payload sequentially.

In one example, the first portion is fixed in size (according to a configuration set by the eNB). Since its size will be relatively small (a low number of bits), a robust coding method can be used to encode and decode this first part (e.g. the known standardised and robust Reed-Muller code in LTE). The second portion's size will then become known after decoding the first portion, that is to say that when the first portion is decoded, the eNB knows exactly how the UE has bundled a multiplicity of A/N bits regarding a multiplicity of codewords. For example consider a scenario of two codewords per subframe, a bundling window M = 5 subframes and N = 5 cells. This in total without bundling would require a 50 bit payload (i.e. two bits per subframe multiplied by five bits per cell (M) multiplied by the number of cells (N). Say for instance that the eNB 101 has preconfigured the UE 102 using 4 bits via RRC) so that: Bit-1 = 1: dynamic bundling can be used; Bit-2 = 1: spatial bundling can be used; Bit-3 = 1: time bundling can be used; and Bit-4 = 1: cell bundling can be used. At the UE 102, upon decoding all the codewords within the time bundling window (M = 5) from all N cells, the UE 102 prepares a bundling information of: section 303 = 1 bit: dynamic bundling has been used; section 304 = 110: only spatial and time bundling have been used; section 305 = 11110: showing that only 4 subframes per cell have been bundled. At the eNB 101, upon receiving the bundling information (1-110-11110), the eNB understands to expect a payload for portion 302 composed of: 1bit-per subframe multiplied by 2 bits per cell multiplied by 5 cells,; a total of 10 bits.

In another example, the first portion is variable in size and the eNB has to also decode sequentially the sections 303, 304 and 305.

In an alternative solution, the UE chooses one of several fixed steps. The eNB then blind decodes on the possible options. For example, if the original payload is 100

bits, there might be several possible compression levels standardized (e.g. 10/20/30/40 %). In that case, when dynamic bundling mode is enabled, the eNB can blind decode for e.g. 100/90/80/70/60-bit UCI payloads. When a CRC (Cyclic Redundancy Check) succeeds, the correct UCI is found.

A further solution uses a table such as or similar to 10.1.1-1 in TS 36.213 where the eNB configures the maximum code rate (and thus the maximum UCI payload) to the UE and the UE tries to fit a compressed UCI into possible payload sizes which are lower than the maximum configured one. The UE is configured to fit the UCI in all lower payload sizes as well

The signal processing functionality of the embodiments of the invention especially the processing unit of the eNB and the processing device of the UE may be achieved using computing systems or architectures known to those who are skilled in the relevant art. Computing systems such as, a desktop, laptop or notebook computer, hand-held computing device (PDA, cell phone, palmtop, etc.), mainframe, server, client, or any other type of special or general purpose computing device as may be desirable or appropriate for a given application or environment can be used. The computing system can include one or more processors which can be implemented using a general or special-purpose processing engine such as, for example, a microprocessor, microcontroller or other control module.

The computing system can also include a main memory, such as random access memory (RAM) or other dynamic memory, for storing information and instructions to be executed by a processor. Such a main memory also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by the processor. The computing system may likewise include a read only memory (ROM) or other static storage device for storing static information and instructions for a processor.

The computing system may also include an information storage system which may include, for example, a media drive and a removable storage interface. The media drive may include a drive or other mechanism to support fixed or removable storage media, such as a hard disk drive, a floppy disk drive, a magnetic tape drive, an optical disk drive, a compact disc (CD) or digital video drive (DVD) read or write drive (R or RW), or other removable or fixed media drive. Storage media may include, for example, a hard disk, floppy disk, magnetic tape, optical disk, CD or DVD, or other fixed or removable medium that is read by and written to by media drive. The storage media may include a computer-readable storage medium having particular computer software or data stored therein.

In alternative embodiments, an information storage system may include other similar components for allowing computer programs or other instructions or data to be loaded into the computing system. Such components may include, for example, a

removable storage unit and an interface , such as a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory module) and memory slot, and other removable storage units and interfaces that allow software and data to be transferred from the removable storage unit to computing system.

The computing system can also include a communications interface. Such a communications interface can be used to allow software and data to be transferred between a computing system and external devices. Examples of communications interfaces can include a modem, a network interface (such as an Ethernet or other NIC card), a communications port (such as for example, a universal serial bus (USB) port), a PCMCIA slot and card, etc. Software and data transferred via a communications interface are in the form of signals which can be electronic, electromagnetic, and optical or other signals capable of being received by a communications interface medium.

In this document, the terms 'computer program product', 'computer-readable medium' and the like may be used generally to refer to tangible media such as, for example, a memory, storage device, or storage unit. These and other forms of computer-readable media may store one or more instructions for use by the processor comprising the computer system to cause the processor to perform specified operations. Such instructions, generally referred to as 'computer program code' (which may be grouped in the form of computer programs or other groupings), when executed, enable the computing system to perform functions of embodiments of the present invention. Note that the code may directly cause a processor to perform specified operations, be compiled to do so, and/or be combined with other software, hardware, and/or firmware elements (e.g., libraries for performing standard functions) to do so.

In an embodiment where the elements are implemented using software, the software may be stored in a computer-readable medium and loaded into computing system using, for example, removable storage drive. A control module (in this example, software instructions or executable computer program code), when executed by the processor in the computer system, causes a processor to perform the functions of the invention as described herein.

Furthermore, the inventive concept can be applied to any circuit for performing signal processing functionality within a network element. It is further envisaged that, for example, a semiconductor manufacturer may employ the inventive concept in a design of a stand-alone device, such as a microcontroller of a digital signal processor (DSP), or application-specific integrated circuit (ASIC) and/or any other sub-system element.

It will be appreciated that, for clarity purposes, the above description has described embodiments of the invention with reference to a single processing logic. However,

the inventive concept may equally be implemented by way of a plurality of different functional units and processors to provide the signal processing functionality. Thus, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organisation.

Aspects of the invention may be implemented in any suitable form including hardware, software, firmware or any combination of these. The invention may optionally be implemented, at least partly, as computer software running on one or more data processors and/or digital signal processors or configurable module components such as FPGA devices. Thus, the elements and components of an embodiment of the invention may be physically, functionally and logically implemented in any suitable way. Indeed, the functionality may be implemented in a single unit, in a plurality of units or as part of other functional units.

Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the invention. In the claims, the term 'comprising' does not exclude the presence of other elements or steps.

Furthermore, although individually listed, a plurality of means, elements or method steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather indicates that the feature is equally applicable to other claim categories, as appropriate.

Furthermore, the order of features in the claims does not imply any specific order in which the features must be performed and in particular the order of individual steps in a method claim does not imply that the steps must be performed in this order. Rather, the steps may be performed in any suitable order. In addition, singular references do not exclude a plurality. Thus, references to 'a', 'an', 'first', 'second', etc. do not preclude a plurality.

Although the present invention has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present invention is limited only by the accompanying claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognise that various

features of the described embodiments may be combined in accordance with the invention. In the claims, the term ‘comprising’ or “including” does not exclude the presence of other elements.

Claims

1. A method for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the method comprising: in a wireless communication unit; generating and transmitting an ACK/NACK bundling instruction; in a wireless communication device, receiving the transmitted ACK/NACK bundling instruction, receiving one or more codewords transmitted by one or more wireless communication elements, generating a ACK/NACK response in respect of each received codeword, bundling a plurality of generated ACK/NACK responses based on the received bundling instruction to generate an ACK/NACK payload, transmitting the ACK/NACK payload and transmitting bundling information relating to properties of the generated ACK/NACK payload; and at the wireless communication unit, receiving the ACK/NACK payload and bundling information, and decoding the ACK/NACK payload based on the received bundling information.

2. The method of claim 1 wherein generating the bundling instruction is based on at least one of: ACK/NACK statistics; available Control channel resources; whether a wireless communication device is power limited; total CSI (Channel State Information) payload; whether a conventional ACK/NACK feedback size exceeds a specified limit; the throughput requirements of a communications link between the wireless communication unit and the wireless communication device.

3. The method of claim 1 or 2 wherein the bundling instruction contains at least one of the following: whether or not to bundle ACK/NACK responses; which bundling modes can be used for bundling; a number of errors that are permitted in an ACK/NACK payload.

4. The method of claim 3 wherein a bundling mode is: spatial; time; frequency (cell); allows multiple ACK/NACK bits per Transport Block, or any combination thereof.

5. The method of any preceding claim including choosing a bundling mode, which is allowed by the received bundling instruction, so that a size of an ACK/NACK payload is minimised.

6. The method of any preceding claim wherein bundling information comprises at least one of the following: whether or not the ACK/NACK payload is bundled; a bundling mode used for bundling the ACK/NACK responses; identities of subframes associated with bundled ACK/NACK

responses; identities of Component Carriers associated with bundled ACK/NACK responses, identities of Transport Blocks associated with bundled ACK/NACK responses.

7. The method of any preceding claim wherein the bundling instruction includes an indication of what information is to be included in the bundling information.

8. The method of any preceding claim wherein the ACK/NACK payload and bundling information are transmitted as an ACK/NACK codebook with the bundling information preceding the ACK/NACK payload.

9. The method of claim 8 wherein the ACK/NACK codebook has a size chosen from a set of predetermined fixed sizes and wherein the codebook is decoded by blind decoding based on knowledge of said predetermined fixed sizes.

10. The method of any preceding claim wherein the wireless communication system is an LTE system, and the HARQ process is a downlink HARQ process, the wireless communication unit is an eNB and the wireless communication device is a User Equipment which receives codewords from the eNB.

11. A wireless communication unit for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the wireless communication unit including a processing unit arranged to generate an ACK/NACK bundling instruction, and wherein the wireless communication unit is arranged to transmit, to a wireless communication device, the ACK/NACK bundling instruction; receive from the wireless communication device, an ACK/NACK payload comprising an ACK/NACK response in respect of at least one codeword received by the wireless communication device and bundling information relating to properties of the ACK/NACK payload; and wherein the processing unit is arranged to decode the ACK/NACK payload based on the received bundling information.

12. A wireless communication device for implementing a Hybrid Automatic Repeat Request (HARQ) process with ACK/NACK bundling in a wireless communication system, the wireless communication device being arranged to; receive an ACK/NACK bundling instruction and at least one codeword; and wherein the wireless communication device includes a processing device arranged to; generate an ACK/NACK

response in respect of each received codeword, bundle a plurality of generated ACK/NACK responses based on the received bundling instruction to generate an ACK/NACK payload; and generate bundling information relating to properties of the ACK/NACK payload; and wherein the wireless communication device is arranged to transmit the ACK/NACK payload and bundling information.

13. The wireless communication device of claim 12 wherein the processing device is arranged to calculate ACK/NACK payload sizes for a plurality of bundling modes and to select the bundling mode which provides the smallest ACK/NACK payload size.

14. A non-transitory computer readable medium having computer readable instructions stored thereon for execution by a processor to perform the method according to any of claims 1-10.

15. The non-transitory computer readable medium of claim 14 comprising at least one from a group consisting of: a hard disk, a CD-ROM, an optical storage device, a magnetic storage device, a Read Only Memory, a Programmable Read Only Memory, an Erasable Programmable Read Only Memory, EPROM, an Electrically Erasable Programmable Read Only Memory and a Flash memory.

16. The method of any of claims 1 to 9 wherein the wireless communication system is a NR (New Radio) system, and the HARQ process is a downlink HARQ process, the wireless communication unit is a gNB and the wireless communication device is a User Equipment which receives codewords from the gNB.

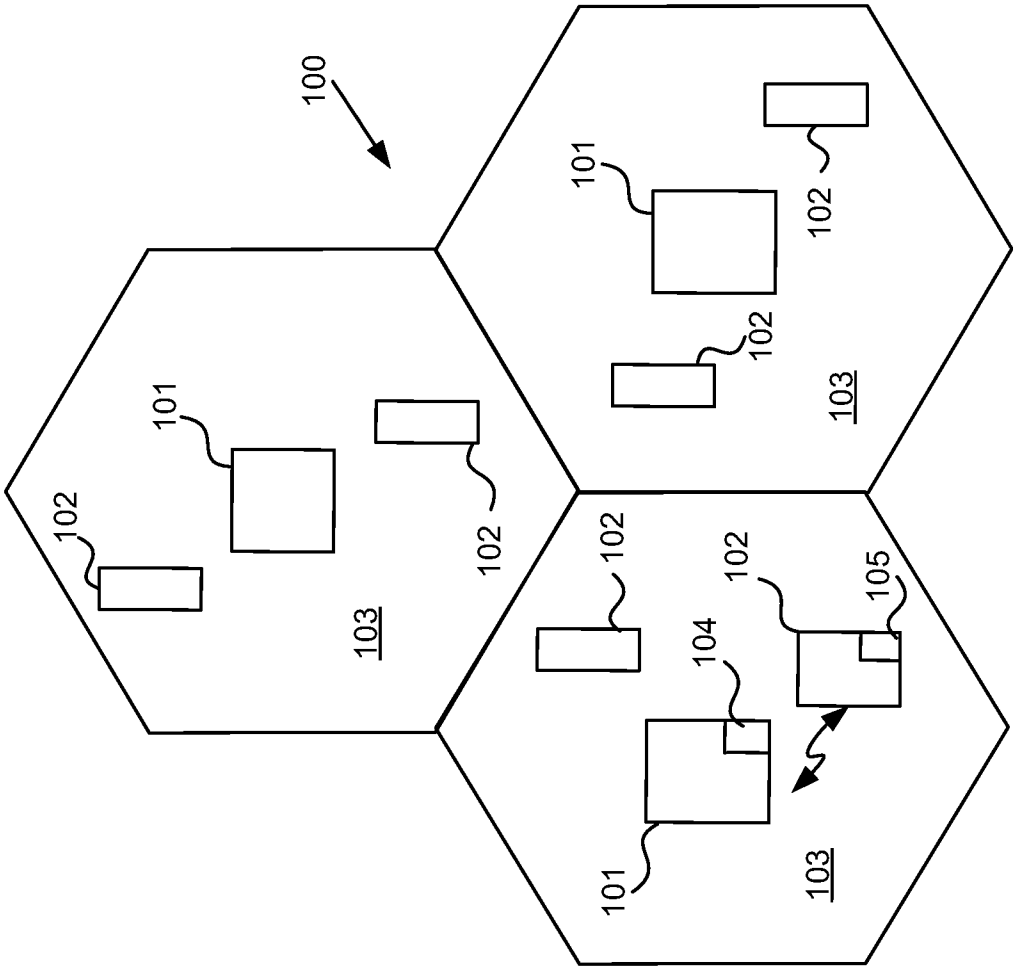


FIGURE 1

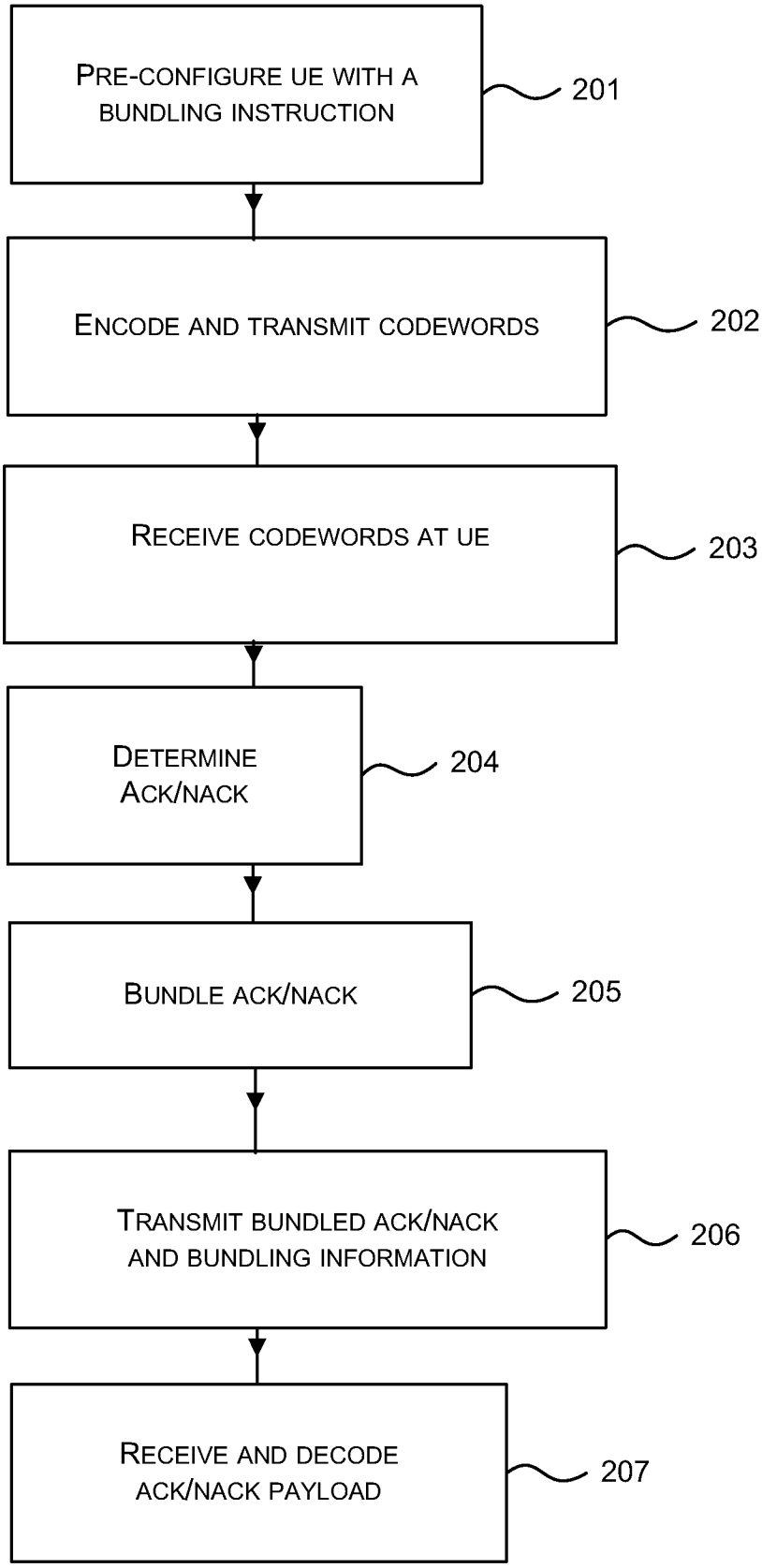

PRE-CONFIGURE UE WITH A BUNDLING INSTRUCTION
201
ENCODE AND TRANSMIT CODEWORDS
202
RECEIVE CODEWORDS AT UE
203
DETERMINE ACK/NACK
204
BUNDLE ACK/NACK
205
TRANSMIT BUNDLED ACK/NACK AND BUNDLING INFORMATION
206
RECEIVE AND DECODE ACK/NACK PAYLOAD
207

FIGURE 2

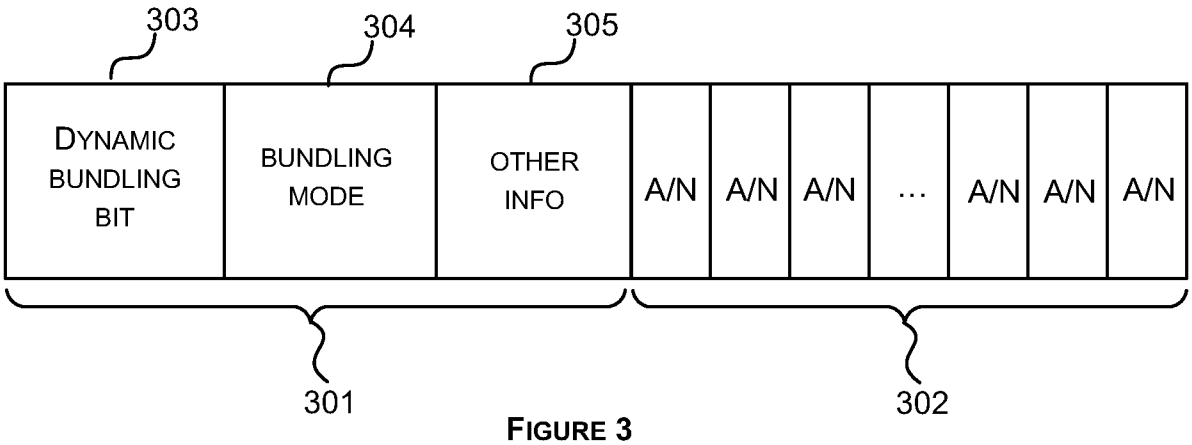


FIGURE 3

Bundling mode	**Extra HARQ ACK/NACK payload**
No bundling	No extra payload: ACK/NACK bits only
Spatial bundling only (bundling_mode=0 or 1	1 bit
Spatial and time bundling (bundling_mode = 00,10, 01 or 11	2 + N bits
Spaital and cell bundling (bundling_mode = 00, 10, 01 or 11	2 + M bits
Spaital, time and cell bundling (bundling_mode = 000, 100,.. etc ... 111)	3 + N + M bits

FIGURE 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/116328

A. CLASSIFICATION OF SUBJECT MATTER

H04W 4/00(2018.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; H04Q; 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)

CNKI, CNABS, CNTXT, VEN, EPTXT, USTXT: HARQ, ACK, NACK, feedback, codeword, payload, encoding

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012026935 A1 (PARK KYU JIN ET AL.) 02 February 2012 (2012-02-02) description, paragraphs [0048]-[0062]	1-16
A	CN 101998507 A (ZTE CORP) 30 March 2011 (2011-03-30) the whole document	1-16
A	CN 105580420 A (SHARP KK) 11 May 2016 (2016-05-11) the whole document	1-16
A	CN 101636989 A (SAMSUNG ELECTRONICS CO LTD) 27 January 2010 (2010-01-27) the whole document	1-16

☐ 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	Date of mailing of the international search report
26 February 2018	**05 March 2018**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/116328

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		US 2015085719 A1	26 March 2015
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		EP 2137908 A1	30 December 2009