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(54) Title: TRANSMISSION TECHNIQUES IN A CELLULAR NETWORK

(57) Abstract: Transmission techniques in a cellular network are described which are particularly appropriate for use with radio systems operating in unlicensed spectrum. An enhanced listen before talk procedure prepares a full slot for transmission commencing when transmission resources are obtained, but only the portion of that slot that fits in the time remaining in the slot in which the resources are obtained is actually transmitted. Procedures are then provided for transmission of the remaining data in a later slot.

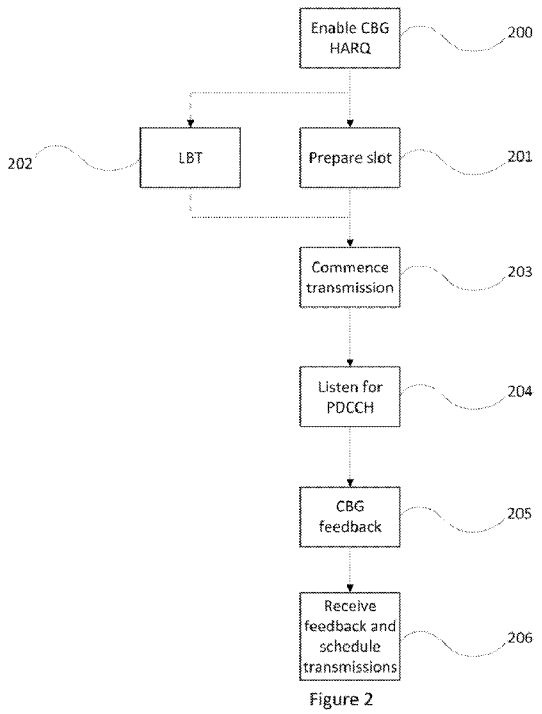


Figure 2

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Transmission Techniques in a Cellular Network

Technical Field

[1] The following disclosure relates to transmission techniques in a cellular network, and in particular to physical layer techniques in Listen Before Talk radio systems.

Background

[2] 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.

[3] In cellular wireless communication systems User Equipment (UE) is connected by a wireless link to a Radio Access Network (RAN). The RAN comprises a set of base stations which provide wireless links to the UEs located in cells covered by the base station, and an interface to a Core Network (CN) which provides overall network control. As will be appreciated the RAN and CN each conduct respective functions in relation to the overall network. For convenience the term cellular network will be used to refer to the combined RAN & CN, and it will be understood that the term is used to refer to the respective system for performing the disclosed function.

[4] 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 one or more macro-cells are 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 one or more cells are supported by a base station known as a gNB. NR is proposed to utilise an Orthogonal Frequency Division Multiplexed (OFDM) physical transmission format.

[5] The NR protocols are intended to offer options for operating in unlicensed radio bands, to be known as NR-U. When operating in an unlicensed radio band the gNB must compete with other devices for physical medium access. For example, Wi-Fi, NR-U, and LAA may utilise the same physical medium resources.

[6] In order to share resources a Listen Before Talk (LBT) protocol is proposed in which a gNB monitors the available resources and only commences transmissions when suitable resources are available. Once the LBT is successful (the resources are “won”), the gNB gains access to the resources for up to the Channel Occupancy Time (COT) provided there is no interruption of transmissions for more than a pre-defined interval (for example 16μs).

[7] Consequently, a gNB may gain access to the physical medium at any point time, and this may fall anywhere in the slot timing relevant cell. However, in conventional systems, transmissions can only start at slot boundaries (symbol 0 or 7 of the subrame) thus limiting available resources. Even if transmission can commence at any symbol boundary, in the slot in which medium access is gained the gNB will only have some of the symbols in that slot for its UL and DL traffic. Also, the gNB will not know how many symbols will be available until access to the resources is gained through LBT.

[8] Figure 1 shows an example of a gNB gaining access to the physical medium during a slot. At region 100 the gNB is listening for access and succeeds in finding available resources at 101.

The COT 102 available to the gNB thus spans part of a first slot 103, a whole second slot 104, and part of a third slot 105.

[9] A gNB could prepare a number of mini-slot transmissions corresponding to possible numbers of symbols available for transmission in the first slot, but this requires significant pre-processing by the gNB, and only some mini-slot lengths are supported (2, 4, or 7 symbols). Alternatively, a series of short mini-slots (2 symbols) could be prepared and used to fill the available symbols after LBT success (provided at least 2 symbols are available). However, the 2nd (and subsequent) mini-slot scheduling must be done within 2 OS, and there are DMRS and DCI overheads in each slots. Also, not all lengths can be covered (2, 4, or 7 symbols).

[10] There is therefore a requirement for a method to efficiently utilise resources in a partial slot after LBT success.

Summary

[11] 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.

[12] There is provided a method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a base station having predefined symbol length & timing, and slot length & timing, and comprising the steps of preparing a transmission slot corresponding to the length of the predefined slot length, the transmission slot comprising a TB of data; listening for access to transmission resources, and acquiring access to those transmission resources; commencing transmission of the transmission slot to the UE at the first available predefined symbol boundary after acquisition of the transmission resources; ending transmission of the transmission slot at the first predefined slot boundary after commencing transmission; and subsequently transmitting, in a subsequent slot, a section of the TB that could not be transmitted prior to the first predefined slot boundary.

[13] The transmission slot may be transmitted on the PDSCH.

[14] The subsequent transmission may be dependent on CBG-level HARQ feedback.

[15] The CBG-level HARQ feedback may indicate unreceived CBGs by indicating the last-received, or first unreceived, CBG.

[16] The method may further comprise the step of activating CBG-level HARQ for at least downlink transmissions on PDSCH via an RRC message.

[17] The subsequent transmission may be performed automatically prior to receipt of any HARQ feedback.

[18] The transmission slot may be transmitted on the PDSCH for which TB-level HARQ is configured via RRC.

[19] TB-level HARQ feedback may be transmitted by the UE after transmission of a complete TB in more than one separate transmission.

[20] The subsequent transmission may be made in a slot subsequent to the slot in which transmission of the transmission slot stated, but within the same COT.

[21] The subsequent transmission may utilise the same HARQ ID, RV, and NDI value as the transmission of the transmission slot.

[22] The transmission slot may comprise a DCI message for transmission on the PDCCH.

[23] The DCI message on the PDCCH may not be transmitted in the first symbol of a predefined slot.

[24] There is also provided a method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a UE having predefined symbol length & timing, and slot length & timing, and comprising the steps of listening in each symbol for PDCCH transmitted from a base station until a DCI for the UE is received; receiving symbols from the base station as indicated by the DCI until the end of the slot in which the DCI was received, the symbols comprising a first section of a TB; receiving a second set of symbols in a subsequent slot comprising a second section of the TB; and combining the first and second sections to form a complete TB.

[25] The method may further comprise the step of transmitting CBG-level HARQ feedback after receipt of the first section of the TB.

[26] The method further comprise the step of transmitting TB-level feedback after receipt fo of the second section of the TB.

[27] The symbols may be received on the PDSCH.

[28] There is also provided a method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a UE having a predefined symbol length & timing, and slot length & timing, and comprising the steps of listening in each symbol for PDCCH transmitted from a base station until a DCI for the UE is received; transmitting symbols from the UE to the base station as indicated by the DCI until the end of the slot in which the DCI was received, the symbols comprising a first section of a TB; and transmitting a second set of symbols in a subsequent slot comprising a second section of the TB.

[29] The method may further comprise the step of receiving CBG-level HARQ feedback from the base station, wherein the second set of symbols are transmitted in response to that feedback.

[30] The CBG-level HARQ feedback may indicate the last received CBG in the TB, or the first unreceived CBG in the TB.

[31] The method may further comprise the step of receiving TB-level HARQ feedback from the base station, wherein the second section of the TB is transmitted prior to receiving that feedback.

[32] The symbols, and second set of symbols, may be transmitted on the PUSCH.

[33] There is also provided a method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a base station having predefined symbol length & timing, and slot length & timing, and comprising the steps of preparing a transmission slot corresponding to the length of the predefined slot length; listening for access to transmission resources, and acquiring access to those transmission resources; commencing transmission of the transmission slot to the UE at the first available predefined symbol boundary after acquisition of the transmission resources, the first symbol comprising a DCI corresponding to the transmission slot; receiving symbols comprising a first section of a TB from the UE in an UL part of the transmission slot; and receiving symbols comprising a second section of the TB from the UE in a subsequent transmission slot.

[34] The method may further comprise the step of transmitting CBG-level feedback after receipt of the first section of the TB, wherein the feedback relates to all CBGs of the TB.

[35] The feedback may indicate the last-received, or first unreceived, CBG of the TB.

[36] The method may further comprise the step of activating CBG-level feedback for the PUSCH utilising an RRC message.

[37] The method may further comprise the step of transmitting TB-level feedback after receipt of the second section of the TB.

[38] There is provided a base configured to perform the relevant methods described hereinbefore.

[39] There is also provided a UE configured to perform the relevant methods described hereinbefore.

[40] 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

[41] 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.

[42] Figure 1 shows an example of resources in an LBT system;

[43] Figure 2 shows a method of data transmission;

[44] Figures 3 and 4 show partial slot transmission on a downlink; and

[45] Figures 5 and 6 show partial slot transmission on an uplink.

Detailed description of the preferred embodiments

[46] 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.

[47] The following disclosure provides a method to utilise resources in a partial slot following LBT success. According to the disclosure the gNB prepares a normal slot for transmission, wherein the slot comprises a DCI and symbols representing a Transport Block (TB) of data. Transmission of the prepared slot is commenced on the first available symbol after LBT success. That is, the DCI message is transmitted in the first symbol after LBT success (even though it is not the first symbol of the normal gNB slot timing). The gNB continues transmission of the slot until reaching the next slot boundary (according to the absolute timing of the gNB for normal transmissions – i.e. prior to reaching the end of the prepared slot assuming the transmission started part-way through the slot) at which point it stops transmitting the prepared slot and reverts to a normal transmission aligned with the gNB slot timing.

[48] The gNB then schedules transmission of any remaining section of the TB which could not be transmitted prior to reaching the gNB slot boundary either immediately or in a subsequent slot. The method thus allows utilisation of all available resources in an efficient manner by fully utilising the remaining parts of a slot after LBT success.

[49] Figure 2 shows a method of transmitting data in an LBT system. The process assumes transmission may commence at any symbol boundary within a slot. In the following disclosure the terms “gNB slot” and “gNB slot boundary” will be used to refer to the normal slot and boundary timing for the relevant gNB. The term “transmission slot” will be used to refer to a

prepared set of symbols for transmission, having a length equal to a gNB slot, which may be transmitted starting at a time determined by the gNB but not necessarily aligned with a gNB slot and gNB slot boundary.

[50] At step 200 the gNB enables CBG-level HARQ for the relevant gNB/UE connection. CBG-level HARQ is configured via RRC messaging and may be configured independently for DL (PDSCH) and UL (PUSCH). CBG HARQ applies a HARQ process at CBG level, thus allowing (re-)transmission of only those CBGs not transmitted or not properly received within a first gNB slot. This contrasts with TB level HARQ in which HARQ messaging applies to a whole TB and the whole TB is re-transmitted even if only a single CBG is not received.

[51] At step 201 the gNB prepares a transmission slot for use when the gNB obtains access to transmission resources. Although referred to as a transmission slot, the prepared slot may be a bi-directional slot. The preparation may be performed prior to, or in parallel with, the gNB performing an LBT process at step 202.

[52] Once the gNB obtains access to the transmission resources the gNB commences transmission of the transmission slot on the PDSCH at the first symbol boundary (step 203). At step 204 the UE listens for PDCCH in all symbols, and once detected applies the received DCI parameters using the received PDCCH start as the initial time reference for the slot.

[53] Transmission of the transmission slot continues until the next gNB slot boundary at which point transmission stops. The gNB reverts to normal transmission scheduling aligned with the gNB slot boundaries until the end of the COT.

[54] At step 205 the UE applies CBG feedback for the received, and not received, CBGs. At the UE, CBGs in the part of the transmission slot that was transmitted should have been successfully received (or failed due to transmission errors), but those in the part of the transmission slot falling after the end of the gNB slot were not transmitted and so could not have been received. The UE thus transmits HARQ feedback indicating the CBGs which were successfully received, and those which were not.

[55] At step 206 the gNB receives the HARQ feedback and schedules re-transmission of those CBGs indicated as not received (albeit this re-transmission is in fact the first transmission of some CBGs).

[56] Transmission continues in the conventional manner, including transmission of data that did not fit in the first partial slot, until the end of the COT. The method of Figure 2 thus allows use of all symbols within a COT, without requiring excessive pre-processing or preparation of transmission signals in very short time intervals. Although some of the prepared transmission slot is not ultimately transmitted, the burden of this preparation is not high and is not required on a very short timescale.

[57] Figure 3 shows an example slot using the process of Figure 2. gNB slot timing is shown at 300. A transmission slot 301 is prepared for transmission, comprising CBGs 302.

[58] During the period 302 the gNB performs an LBT process until access is successful at 303. At symbol 303 the gNB commences transmission of the prepared transmission slot 301. Transmission of the transmission slot 301 stops at the end of Symbol 4, at the end of the gNB slot 300. At this point the CBGs 304 mapped to symbols 1 – 4 have been transmitted, but the remaining CBGs 305 have not been transmitted. The HARQ process at step 205 indicates the transmission status of each of the CBGs appropriately, with the unreceived CBGs (305 & any CBGs with transmission errors) indicated as failures. The gNB then reschedules the (re-)transmission of those CBGs in the conventional way. Transmission after the end of the gNB slot

300 continues with conventional slots until the end of the COT. Full use is thus made of all available resources in the COT.

[59] The transmission of Figure 3 is shown more generally in Figure 4. The first four data symbols 400 of transmission slot 301 are transmitted in the first gNB slot 300 using PID 1. Transmission in the second gNB slot 401 includes data scheduled for that slot, and may also include the CBGs from transmission slot 301 not transmitted in the first gNB slot 300. Those CBGs are transmitted using PID 1 such that the UE can relate them to the CBGs received in the first gNB slot 300, and thus compile a complete set of CBGs, i.e. a complete TB.

[60] Figure 5 shows an example transmission slot 500 including DL 501 and UL 502 regions. In this example, there are sufficient symbols in the first gNB slot for the first 10 symbols, which include the first 4 UL symbols. CBGs 503 are mapped to those symbols and can thus be successfully transmitted by the UE to the gNB in the first gNB slot 600, as shown in Figure 6. Transmission continues in the second gNB slot 601, using a different PID (2 in this example). The remaining CBGs are scheduled for transmission in a subsequent gNB slot 602, in which they are transmitted by the UE with PID 1 for combination with the previously transmitted CBGs to form the complete TB.

[61] The method described with reference to Figure 2 thus allows the transmission of a first partial slot to fully utilise the remaining symbols available in the gNB slot in which LBT succeeds. Symbols which do not fit into that first slot are then transmitted by the gNB or UE in a later slot within the COT. To enable this process the gNB transmits, and the UE receives, a DCI in the first slot after LBT succeeds as if it were transmitted at the gNB slot boundary. Subsequently the UE and gNB monitor the gNB slot timing to interrupt transmission at the next gNB slot boundary, after which conventional transmission is utilised. CBG HARQ processes allow the identification and (re-)transmission of CBGs not successfully transmitted and received.

[62] CBG-level HARQ has been defined to allow indication of sparsely located erroneous CBGs within a TBS. However, this is not a good match for the type of errors found in the method disclosed hereinbefore. In this process, all CBGs after a certain one will be missing at the receiver and the transmitter is aware of this. A modified CBG-level HARQ process may thus be implemented in which the HARQ acknowledgement message indicates the set of CBGs not received more efficiently for these particular circumstances. For example, the message may indicate the last successfully received CBG, or the first not-received CBG. It is then implicit that all remaining CBGs were not received successfully.

[63] Since the gNB (or UE) knows which CBGs have not been transmitted, it can automatically schedule transmission of those CBGs in a subsequent gNB slot (even in the slot immediately following the first gNB slot in which the transmission slot was partially transmitted. The UE (or gNB) can then transmit a single HARQ response for the whole TB (TB-level HARQ). Such a technique may improve the latency of transmission as there is no ACK/NACK round-trip delay prior to transmission of the CBGs not transmitted in the first gNB slot. Furthermore, the feedback overhead is reduced is only one HARQ message is sent for the whole TB.

[64] If automatic transmission of missed CBGs is utilised (i.e. TB-level HARQ), the HARQ timing should be set appropriately to allow time for the subsequent CBGs to be transmitted before a HARQ message is sent.

[65] The receiver must be able to identify subsequently transmitted CBGs and combine them with the initial transmission to reassemble the complete TB. To enable this the subsequent transmission must have the same HARQ ID & RV values and must not toggle NDI compared to the first transmission. Thus, when a receiver receives two transmissions with the same HARQ ID, RV, and NDI, and without sending a HARQ response, it can combine the two transmissions to

form the full TB. Furthermore, the UE can assume that the CBGs in the second transmission have the same characteristics as indicated in the first transmission.

[66] When automatic transmission of the remaining CBGs is utilised, CBG-level feedback is not required, and therefore need not be activated for the UE (that is, step 200 can be omitted from the method described above). Conventional TB-level feedback can thus be utilised.

[67] There may be some circumstances where CBG-level feedback is preferable, for example if scheduling resources are limited compared to the traffic resources. CBG-level feedback reduces timing constraints on the transmission of the remaining CBGs after the initial partial transmission slot.

[68] Although the above description has been given primarily with regard to DL transmission, the same principles apply to uplink transmissions.

[69] Partial TB transmission can be applied either based on standard CBG re-transmission, modified CBG re-transmission (using a modified HARQ message as described above), or implicit/automatic CBG retransmission. Each option carries differing overheads. The first two options require a CBGTI overheard, and all options add a partially transmitted CBG overhead (because CBGs do not map directly to symbols, a partial CBG may be transmitted at the end of the first gNB slot and the whole CBG must be re-transmitted).

[70] Signalling overhead corresponds to 6 bits in DCI (6 bits of CBGTI) compared to typical unicast DCI of 44bits (+ 16 bits CRC). This is negligible vs the number of bits transmitted within a slot. The bigger the TB the more it is negligible (it scales down). For implicit CBG re-transmission no CGBTI is required and so there is no additional signalling overhead.

[71] The average partial CBG transmission overhead is 0.5*(CBG length).

[72] It should be noted that the alternative option of multiple mini slots has a higher DCI overhead, as there is one DCI per mini slot, even if the subsequent slot can have compressed DCI and rely on information received in the first DCI. As a minimum, ~20bits +16 CRC DCI is required for subsequent mini-slot.

[73] The efficiency of the proposed technique, compared to the pre-formation of mini-slots used to fill a partial slot, is set out in the following table.

Effective Nsymb after LBT	2	3	4	5	6	7	8	9	10	11	12	13	14
medium occupancy by minislots	2	2	4	4	6	6	6	9	9	11	11	13	14
minislots config	2	2	2+2	2+2	2+4	2+4	2+4	2+7	2+7	2+2+7	2+2+7	2+7+4	2+7+4
minislot overhead (DMRS only)	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1	1
minislot occupancy loss	0	1	0	1	0	1	2	0	1	0	1	0	0
loss & overhead	0	1	0.5	1.5	0.5	1.5	2.5	0.5	1.5	1	2	1	1
% loss (OS)	0.00	33.33	12.50	30.00	8.33	21.43	31.25	5.56	15.00	9.09	16.67	7.69	7.14
% loss for partial TB - 13 codewords (max SISO)	26.9	17.9	13.5	10.8	9.0	7.7	6.7	6.0	5.4	4.9	4.5	4.1	3.8
% loss for partial TB - 26 codewords (max MIMO 2 layers, 1CW)	13.5	9.0	6.7	5.4	4.5	3.8	3.4	3.0	2.7	2.4	2.2	2.1	1.9
% loss (our case, CB based) - 52	6.7	4.5	3.4	2.7	2.2	1.9	1.7	1.5	1.3	1.2	1.1	1.0	1.0

codewords (max MIMO 4 layers, 1CW)													

[74] The average values for selected parameters are shown in the following table:-

	Average Loss
% loss (OS)	13.94%
% loss for partial TB - 13 codewords (max SISO)	6.7%
% loss for partial TB - 26 codewords (max MIMO 2 layers, 1CW)	3.4%
% loss (our case, CB based) - 52 codewords (max MIMO 4 layers, 1CW)	1.7%

[75] This table shows that partial TB transmission gives at least comparable, and in many cases better efficiency than the mini-slots approach for SISO case (except if 2 OS only are available, which can be considered as a low throughput corner case), and the loss percentage scales down strongly with MIMO layers increase while those of mini-slots approach doesn't.

[76] For example, the percentage of resource loss for 4 layers 1 CW remains below 7% for all durations while it can reach up to 33% for mini-slots approach.

[77] The average percentage of resource loss for is 13.9 % for the minislot approach while it is 6.7%, 3.4% and 1.7% for partial TB transmission respectively for 1,2 and 4 MIMO layers.

[78] The disclosed method therefore provides an efficient method to utilise transmission resources where an LBT process obtains access to a transmission medium part-way through a gNB slot.

[79] In the above description transmission has commenced at the first symbol boundary after access to the transmission resources is obtained. However, it is possible that that transmission may be delayed for any reason, and therefore transmission may commence later. It may therefore be stated that transmitted starts at the first available symbol boundary after access is obtained.

[80] Although not shown in detail any of the devices or apparatus that form part of the network may include at least a processor, a storage unit and a communications interface, wherein the processor unit, storage unit, and communications interface are configured to perform the method of any aspect of the present invention. Further options and choices are described below.

[81] The signal processing functionality of the embodiments of the invention especially the gNB and 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.

[82] 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.

[83] 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.

[84] 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.

[85] 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.

[86] 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 45 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.

[87] 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. 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.

[88] 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.

[89] 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.

[90] 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.

[91] 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 recognise 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.

[92] 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.

[93] 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.

[94] 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 of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a base station having predefined symbol length & timing, and slot length & timing, and comprising the steps of:-

preparing a transmission slot corresponding to the length of the predefined slot length, the transmission slot comprising a TB of data;

listening for access to transmission resources, and acquiring access to those transmission resources;

commencing transmission of the transmission slot to the UE at the first available predefined symbol boundary after acquisition of the transmission resources;

ending transmission of the transmission slot at the first predefined slot boundary after commencing transmission; and

subsequently transmitting, in a subsequent slot, a section of the TB that could not be transmitted prior to the first predefined slot boundary.

2. A method according to claim 1, wherein the transmission slot is transmitted on the PDSCH.

3. A method of data transmission according to claim 1 or claim 2, wherein the subsequent transmission is dependent on CBG-level HARQ feedback.

4. A method of data transmission according to claim 3, wherein the CBG-level HARQ feedback indicates unreceived CBGs by indicating the last-received, or first unreceived, CBG.

5. A method of data transmission according to claim 2 or claim 3, further comprising the step of activating CBG-level HARQ for at least downlink transmissions on PDSCH via an RRC message.

6. A method of data transmission according to claim 1 or claim 2, wherein the subsequent transmission is performed automatically prior to receipt of any HARQ feedback.

7. A method of data transmission according to claim 6, wherein the transmission slot is transmitted on the PDSCH for which TB-level HARQ is configured via RRC..

8. A method of data transmission according to claim 7, wherein TB-level HARQ feedback is transmitted by the UE after transmission of a complete TB in more than one separate transmission.

9. A method of data transmission according to any preceding claim, wherein the subsequent transmission is made in a slot subsequent to the slot in which transmission of the transmission slot stated, but within the same COT.

10. A method of data transmission according to any preceding claim, wherein the subsequent transmission utilises the same HARQ ID, RV, and NDI value as the transmission of the transmission slot.

11. A method of data transmission according to any preceding claim, wherein the transmission slot comprises a DCI message for transmission on the PDCCH.

12. A method of data transmission according to claim 11, wherein the DCI message on the PDCCH is not transmitted in the first symbol of a predefined slot.

13. A method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a UE having predefined symbol length & timing, and slot length & timing, and comprising the steps of :-

listening in each symbol for PDCCH transmitted from a base station until a DCI for the UE is received;

receiving symbols from the base station as indicated by the DCI until the end of the slot in which the DCI was received, the symbols comprising a first section of a TB;

receiving a second set of symbols in a subsequent slot comprising a second section of the TB; and

combining the first and second sections to form a complete TB.

14. A method of data transmission according to claim 13, further comprising the step of transmitting CBG-level HARQ feedback after receipt of the first section of the TB.

15. A method of data transmission according to claim 13, further comprising the step of transmitting TB-level feedback after receipt fo of the second section of the TB.

16. A method of data transmission according to claim 13, wherein the symbols are received on the PDSCH.

17. A method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a UE having a predefined symbol length & timing, and slot length & timing, and comprising the steps of :-

listening in each symbol for PDCCH transmitted from a base station until a DCI for the UE is received;

transmitting symbols from the UE to the base station as indicated by the DCI until the end of the slot in which the DCI was received, the symbols comprising a first section of a TB; and

transmitting a second set of symbols in a subsequent slot comprising a second section of the TB.

18. A method according to claim 17, further comprising the step of receiving CBG-level HARQ feedback from the base station, wherein the second set of symbols are transmitted in response to that feedback.

19. A method according to claim 18, wherein the CBG-level HARQ feedback indicates the last received CBG in the TB, or the first unreceived CBG in the TB.

20. A method according to claim 18, further comprising the step of receiving TB-level HARQ feedback from the base station, wherein the second section of the TB is transmitted prior to receiving that feedback.

21. A method according to any of claims 17 to 20, wherein the symbols, and second set of symbols, are transmitted on the PUSCH.

22. A method of data transmission utilising a Listen-Before-Talk (LBT) transmission protocol in a cellular communications network, the method performed at a base station having predefined symbol length & timing, and slot length & timing, and comprising the steps of :-

preparing a transmission slot corresponding to the length of the predefined slot length;

listening for access to transmission resources, and acquiring access to those transmission resources;

commencing transmission of the transmission slot to the UE at the first available predefined symbol boundary after acquisition of the transmission resources, the first symbol comprising a DCI corresponding to the transmission slot;

receiving symbols comprising a first section of a TB from the UE in an UL part of the transmission slot; and

receiving symbols comprising a second section of the TB from the UE in a subsequent transmission slot.

23. A method according to claim 21, further comprising the step of transmitting CBG-level feedback after receipt of the first section of the TB, wherein the feedback relates to all CBGs of the TB.

24. A method according to claim 22, wherein the feedback indicates the last-received, or first unreceived, CBG of the TB.

25. A method according to claim 22 or claim 23, further comprising the step of activating CBG-level feedback for the PUSCH utilising an RRC message.

26. A method according to claim 21, further comprising the step of transmitting TB-level feedback after receipt of the second section of the TB.

27. A base station configured to perform the method of any of claims 1 to 12, and 22 - 26.

28. A UE configured to perform the method of any of claims 13 to 21.

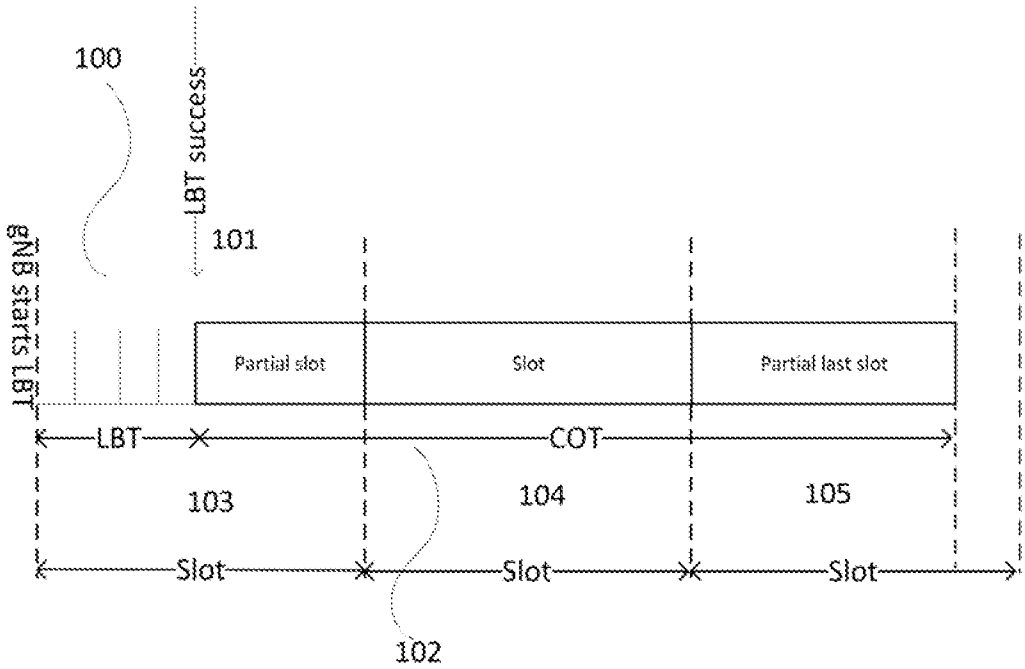

100
LBT success
101
gNB starts LBT
Partial slot
Slot
Partial last slot
LBT
COT
103
104
105
Slot
Slot
Slot
102

Figure 1

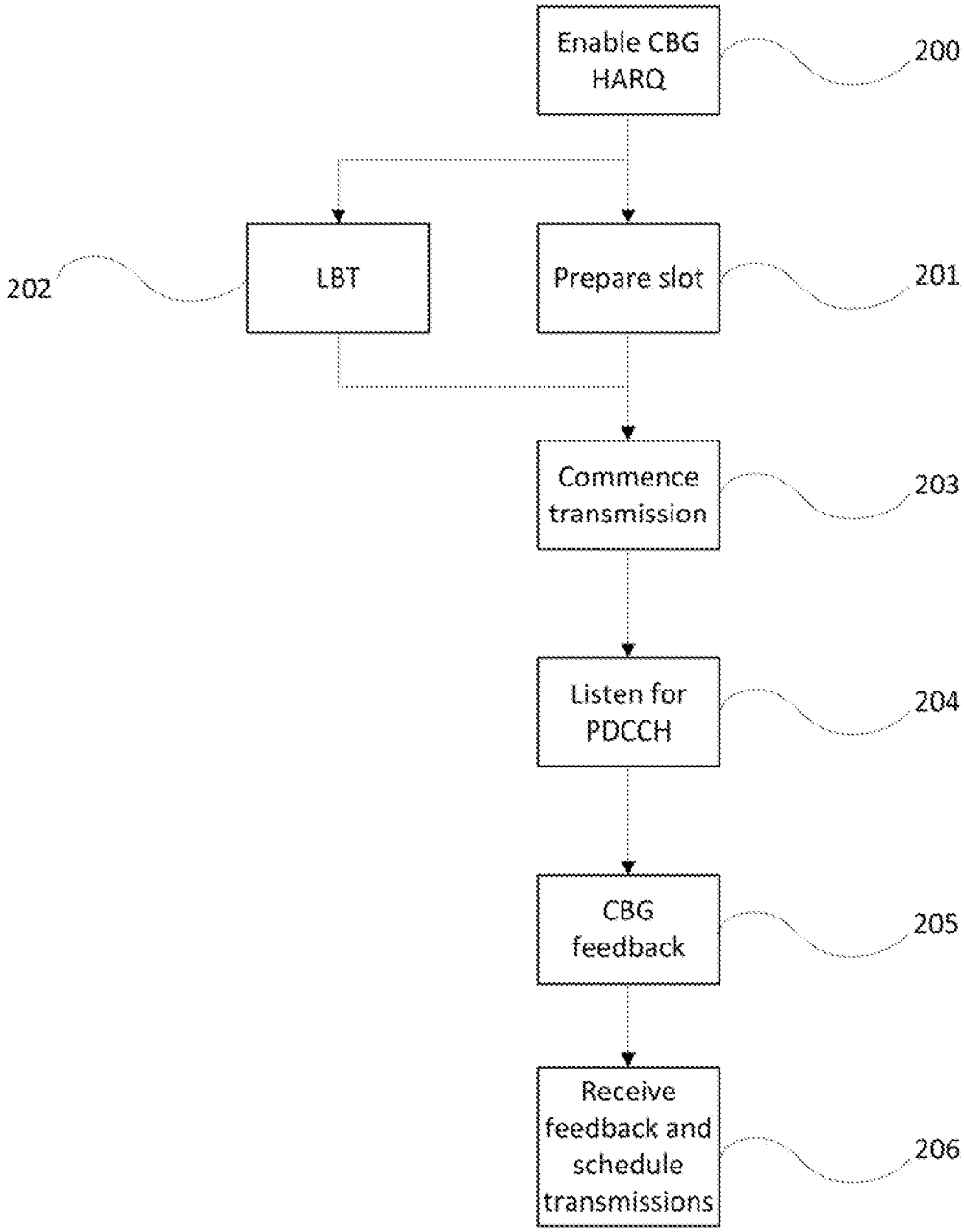

Enable CBG HARQ
200
LBT
202
Prepare slot
201
Commence transmission
203
Listen for PDCCH
204
CBG feedback
205
Receive feedback and schedule transmissions
206

Figure 2

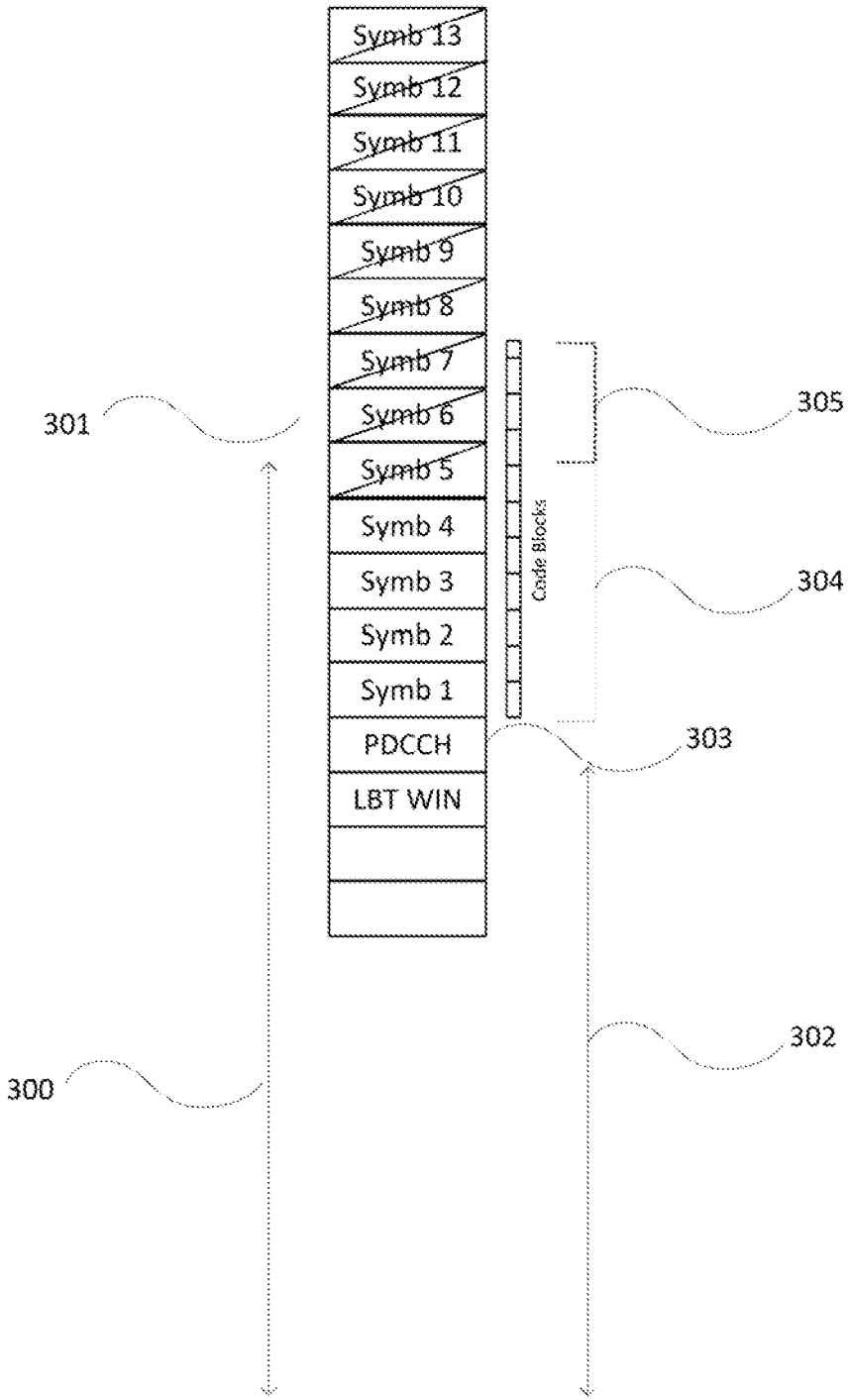

Symb 13
Symb 12
Symb 11
Symb 10
Symb 9
Symb 8
Symb 7
Symb 6
Symb 5
Symb 4
Symb 3
Symb 2
Symb 1
PDCCH
LBT WIN
Code Blocks
301
305
304
303
302
300

Figure 3

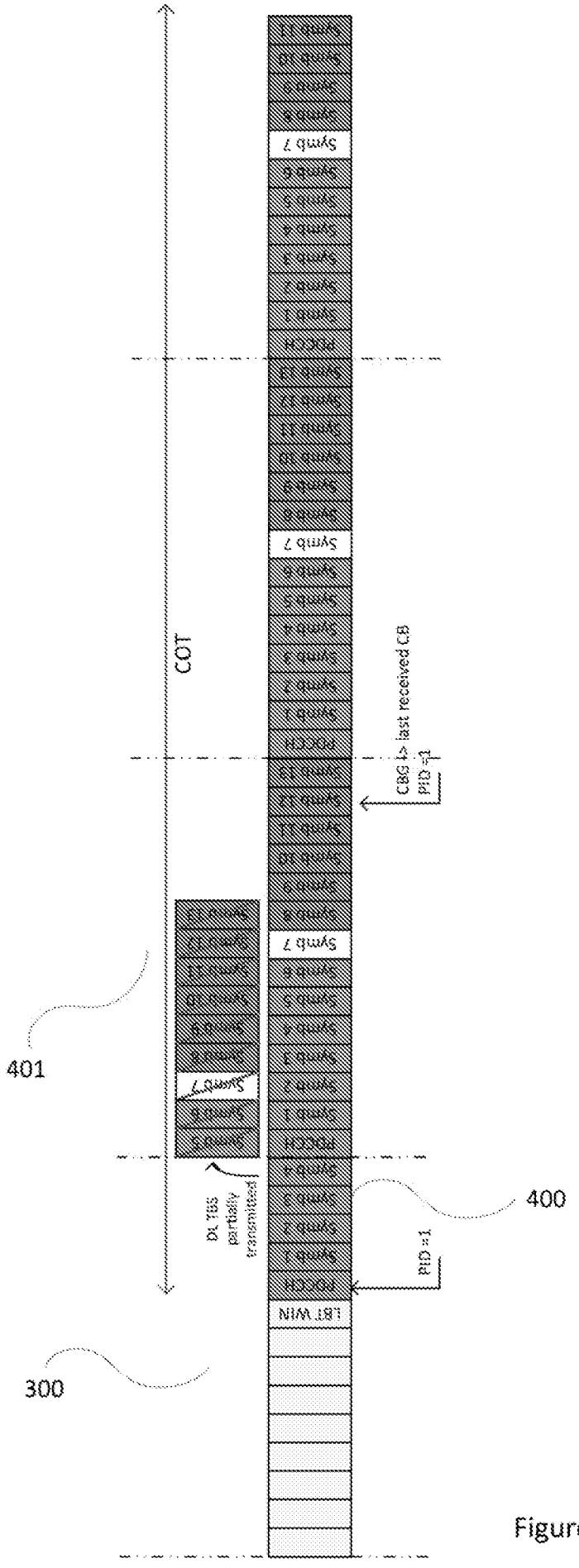

COT
CBG 4> last received CB
PID =1
401
400
DL TBS partially transmitted
PID =1
300

Figure 4

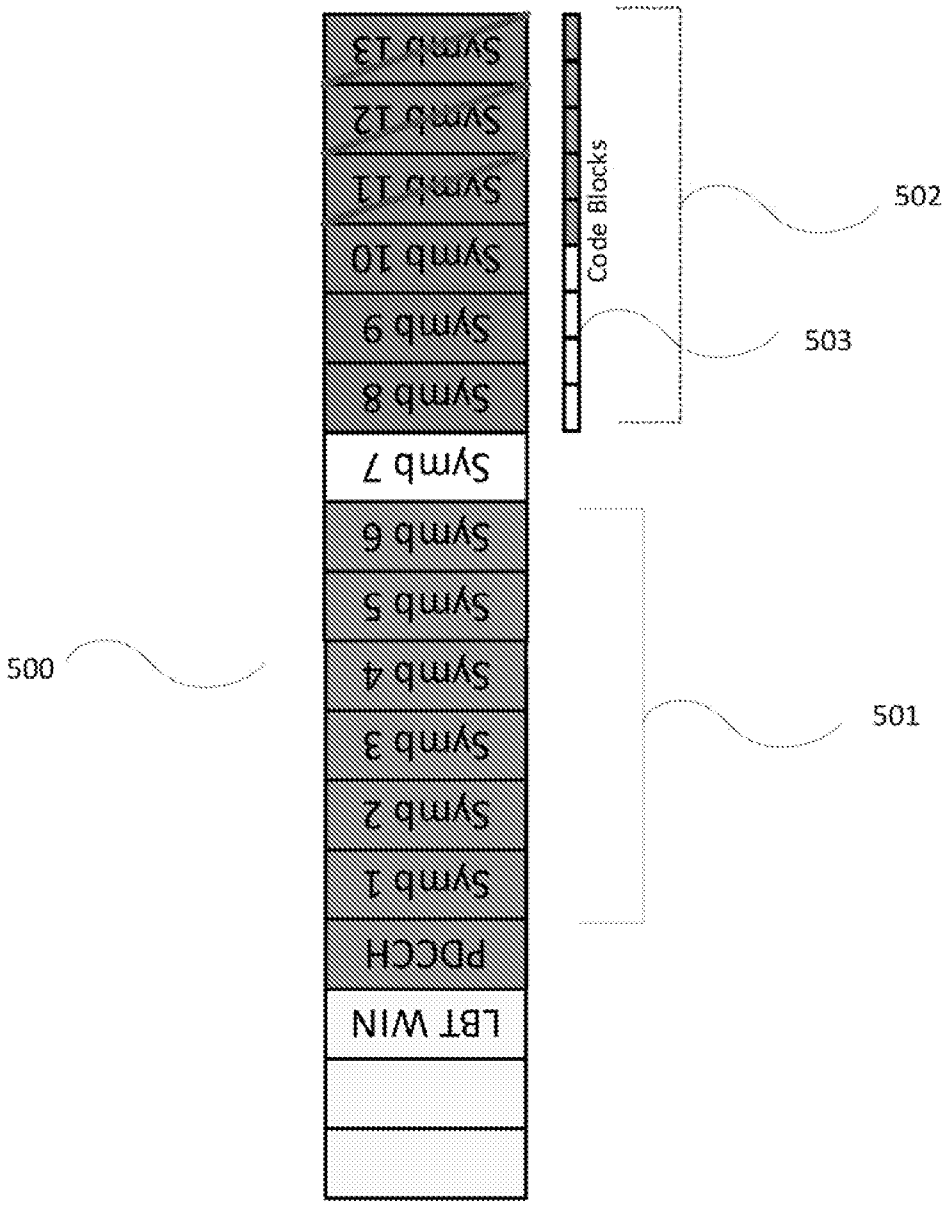

Symb 13
Symb 12
Symb 11
Symb 10
Symb 9
Symb 8
Symb 7
Symb 6
Symb 5
Symb 4
Symb 3
Symb 2
Symb 1
PDCCH
LBT WIN
Code Blocks
500
501
502
503

Figure 5

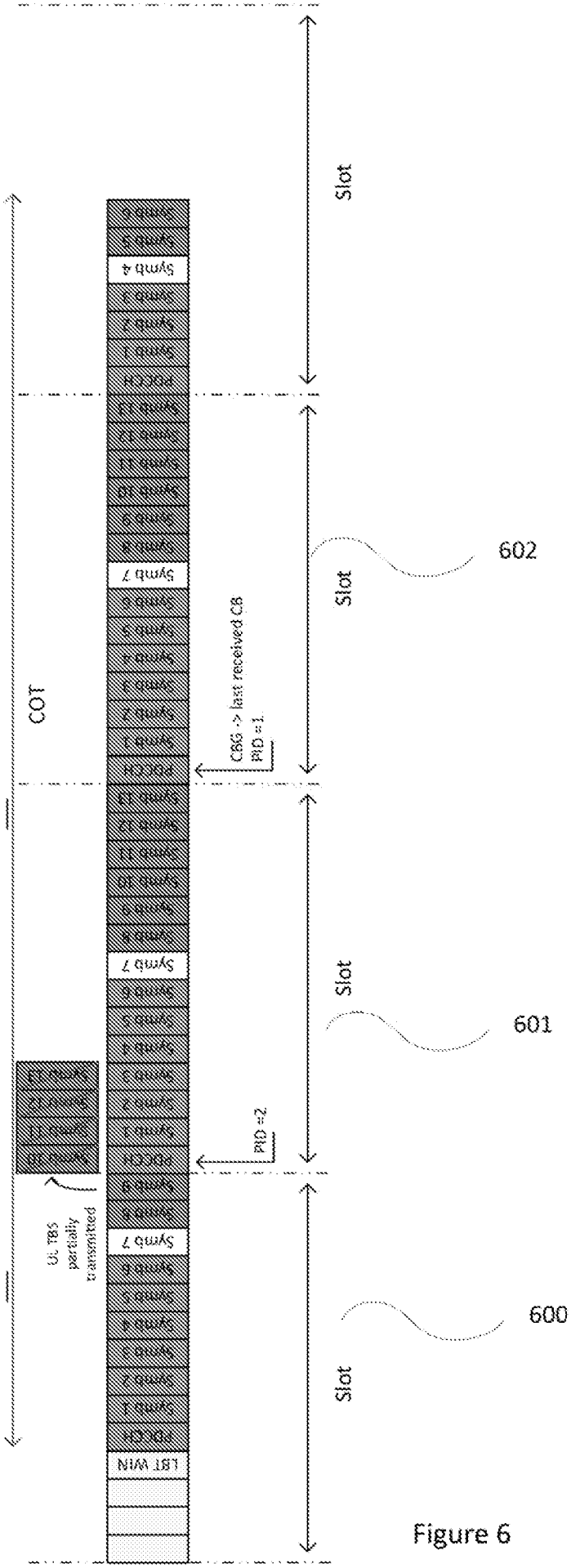

Slot
602
Slot
601
Slot
600
COT
CB6 -> last received CB
PID =1
PID =2
UL TBS partially transmitted
LBT WIN

Figure 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2019/097217

A. CLASSIFICATION OF SUBJECT MATTER

H04W 74/08(2009.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W; 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)

CNABS,CNTXT,CNKI,WOTXT,EPTXT,USTXT,DWPI,3GPP:先听后说，侦听，监听，先听后讲，帧，时隙，节省，节约，边界，边缘，边沿，DCI，LBT，Listen before talk, frame, slot, symbol, save, boundary

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017049560 A1 (PANASONIC INTELLECTUAL PROPERTY CORP AME) 30 March 2017 (2017-03-30) description, page 4, lines 1-27, page 10, line 6 to page 11, line 6	1-28
A	CN 107079494 A (NOKIA CORP) 18 August 2017 (2017-08-18) the whole document	1-28
A	WO 2017052802 A1 (QUALCOMM INC) 30 March 2017 (2017-03-30) the whole document	1-28
A	CN 1295741 A (NOKIA CORP) 16 May 2001 (2001-05-16) the whole document	1-28

☐ 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
27 September 2019	**10 October 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**DUAN,Wei**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2019/097217

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