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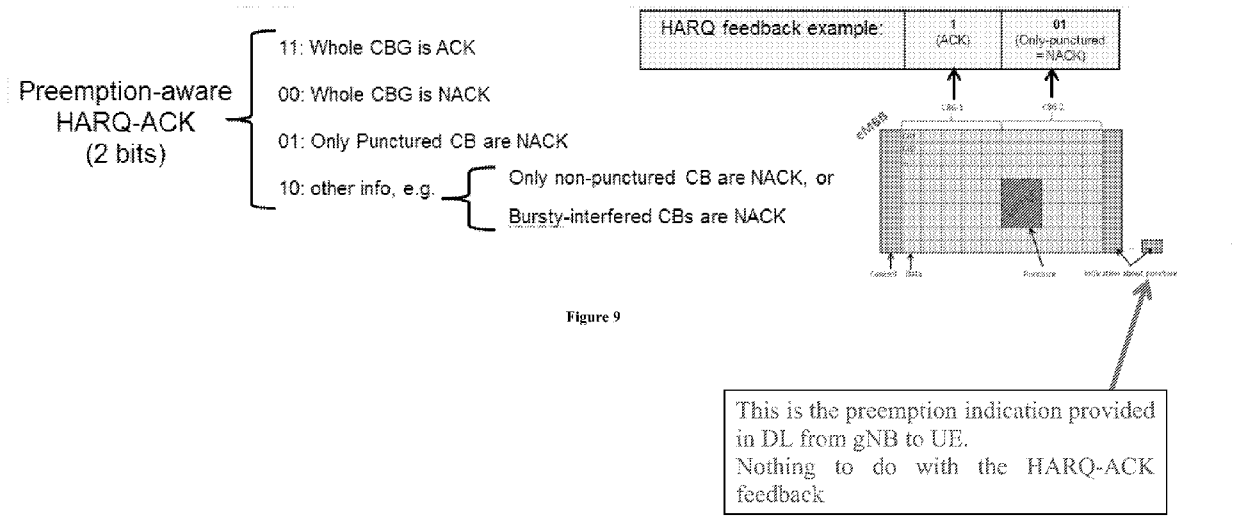


Figure 9

(57) Abstract: A method for enabling access to services provided by a Radio Access Network between first and second wireless communications devices, the method comprising: wherein a HARQ-ACK feedback is generated at the second wireless communication device based on resources pre-empted during the transmission of a transport block from the first wireless communications device so that the second wireless communication device can monitor for pre-empted resources.

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Methods and devices associated with improvements in or relating to Hybrid Automatic repeat requests in New Radio

Technical Field

Embodiments of the present invention generally relate to wireless communication systems and in particular to devices and methods for enabling a wireless communication system to operate, particularly but nor exclusively in conjunction using Hybrid Automatic repeat requests (HARQ) feedback to report downlink data.

Background

Wireless communication systems enable communications which enable devices such as a User Equipment (UE) or mobile device to access a Radio Access Technology (RAT) or Radio Access Network (RAN), 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 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; NR (new radio) and 4G/LTE systems where one or more cells are supported by a base station known as a gNB.

In LTE, a subframe (SF) has a duration of 1 ms and has been the main scheduling unit or Transmission Time Interval (TTI) for transmission. A TTI duration corresponds to a number of consecutive Orthogonal Frequency division Multiplex (OFDM) symbols for a transmission in the time domain (TR 38.804 5.4.7). A 14-symbol SF (for normal cyclic prefix) consists of two 7-symbol slots. Recently, short TTI (sTTI) of size e.g. 2, 3 or 7 symbols has also been introduced.

In NR, the term SF serves as a time reference only. This is still 1ms, but is not now a fixed number of OFDM symbols to be scheduled as it was in LTE. A slot is now the scheduling unit or TTI which is 7 or 14 OFDM symbols long (for a normal cyclic prefix). There are also mini-slots of sub 7 (e.g. 1, 2, 4) OFDM symbols defined.

A transport block (TB) is a set of information bits to be transmitted in one TTI and its size in bits is specified by a transport block size (TBS). A code block (CB) is a subset of TB information bits that are protected by a separate Cyclic Redundancy Check (CRC) and there may be several CBs in each TB. The CB size is limited by a pre-defined maximum value so when the TBS increases, the number of CBs increases too. A few CBs from a TB can be further grouped into a code block group (CBG). This was agreed by 3GPP for NR, to support CBG-level (re)transmissions to improve the efficiency. The term (re)transmission refers to the initial transmission or retransmission of data.

Down link (DL) HARQ refers to the procedure where in a first stage DL data is sent from gNB to UE via a Physical Downlink Shared Channel (PDSCH). Acknowledged/not-acknowledged (ACK/NACK) information is sent from UE to gNB either through a Physical Uplink Control Channel (PUCCH) or a Physical Uplink Shared Channel (PUSCH). This is also referred to as HARQ-ACK feedback. Finally, data is retransmitted from gNB to UE via PDSCH in case NACK/ Discontinuous Transmission (DTX) has been received from UE.

In LTE, each CB is also protected by a CRC and it could have been possible for the UE to provide CB-level HARQ-ACK. However, it was decided to support in standards only TB-level HARQ-ACK to be fed back from the receiver to transmitter (i.e. 1 bit to notify the ACK or NACK of a TB). The advantages from having TB-level HARQ-ACK feedback include a reduced HARQ-ACK feedback overhead and a guaranteed HARQ-ACK transmission reliability in a coverage limited case due to smaller HARQ ACK codebook size. A disadvantage is the low transmission efficiency for data with large payload size since even one erroneous CB in a TB will lead to the retransmission of the whole TB. This was previously deemed to be acceptable considering the HARQ-ACK feedback savings and that the extreme case in LTE is to have only up to 32 CBs per TB in DL (for 20 MHz, 110 PRB, 2 spatial layers transmission).

In NR, there was an agreement (in **RAN1_NR_AH#1**) for *multi-bit HARQ-ACK feedback per TB*. The reason is a combination of the following: the max CB size in NR has been agreed to be 8192 bits, ~25% higher than LTE (6144 bits). However, enhanced Mobile Broadband (eMBB) services will require much larger TBS than LTE to achieve the envisioned high throughputs. This means an increased number of CBs per TB compared to LTE (expected extreme cases may be >100 CBs per TB when eMBB data rate is high). In addition, the introduction of pre-emption-based multiplexing (and the possibility of CB-specific interference to eMBB slot transmission due to other mini-slot transmissions) amplifies the possibility of having single or few erroneous CBs within a TB.

CBG-based (re)transmission has been supported in NR as a possible option to utilize multi-bit HARQ-ACK feedback. In addition, it has been shown that significant spectral efficiency (SE) improvement can be seen with CBG-level versus TB-level HARQ-ACK feedback. As shown in figure 1, there is a cut-off point where the SE benefit from transmission efficiency (i.e. less unnecessary CBs are retransmitted) is overcome by the HARQ-ACK feedback size.

A UE can be configured by higher layer parameter to receive PDSCH transmissions that include code block group (CBG) retransmissions of a transport block. In that case, the UE is also configured a number of CBGs for generating respective HARQ-ACK information bits for an initial reception of a transport block. HARQ-ACK reporting can be performed using the physical uplink shared channel (PUSCH) or the physical uplink control channel (PUCCH) and its various formats.

In NR, it has been also supported to dynamically multiplex data with different transmission duration on the same resource. One of the ways agreed for such sharing in DL was via pre-emption of the longer transmission. For example, if eMBB and Ultra Reliable Low Latency Communication (URLLC) services are multiplexed in DL, it is possible for the gNB to schedule a latency-intolerant URLLC mini-slot transmission within an ongoing eMBB slot transmission, where a part of eMBB transmission will be punctured. This is shown in figure 2. It is also possible for URLLC transmission to use different numerology (i.e. subcarrier spacing, (SCS)) than eMBB transmission. For example, figure 2 may refer to a 7-symbol 15kHz-SCS eMBB transmission spanning 0.5msec, punctured by a 4-symbol 30kHz-SCS URLLC transmission spanning (2/7)*0.5 ≈ 0.143msec.

It is a common understanding within 3GPP that CBs will be mapped frequency-first onto physical resources to facilitate pipeline processing while it might not be precluded for CBs to span multiple symbols, as is the case for CB2 in figure 2. Therefore, it is expected for CBGs to be mapped consecutively in time onto physical frequency/time (f/t) resources. This is shown in figure 3 for no-symbol alignment. Overlapping of neighbouring CBGs may be also possible, e.g. a few CBs may be part of both CBG0 and CBG1.

As a result, a pre-emptive URLLC transmission will puncture only one or few CBGs of the eMBB transmission and there is a possibility that these CBGs will be partially punctured (i.e. only some CBs of a CBG are pre-empted) as illustrated in a simplified scenario shown in figure 4.

It has been agreed to also support, for DL in NR, a pre-emption indication to eMBB UE, indicating the time and/or frequency region of impacted eMBB resources. The main purpose of such pre-emption indication is to assist eMBB data decoding by nulling out the log-likelihood ratios (LLRs) on the impacted eMBB resources. This pre-emption indication can be beneficial for the cases where a) small portion of CBs is pre-empted and/or b) the code rate is low; zero LLR in the above cases gives more chances for successful decoding of the CBs than having random LLR. If such indication is received early enough at UE, so as UE has enough time to use it for decoding impacted CBs before HARQ-ACK feedback generation timing, retransmissions can be reduced. If received late, at least UE can improve its soft combining with retransmission. For HARQ, an LLR value regarding a part of received data from an initial transmission can be soft combined with another LLR value regarding the same part of received data from a retransmission to improve decoding success at UE. For pre-emption, however, the respective LLR values received reflect only the URLLC transmission and carry no useful information and just ARQ (nulling out old LLRs) is better to use instead if pre-emption is known to UE.

Figure 5 illustrates a complete control signalling and feedback flow given the agreements about pre-emption indication and CBG-based multi-bit HARQ-ACK feedback and retransmission.

The potential benefit of having finer-that-CBG-level retransmissions (i.e. retransmissions with lower granularity than CBG-level) has also been considered. For example, the example shown in figure 6, considers 4-symbol URLLC puncturing

on 14-symbol eMBB slots and shows that having CB-level HARQ feedback and retransmission can be much more beneficial than CBG-level HARQ feedback and retransmission. Especially when CBG-size is big (e.g. 9 CBs is the worst case considered in figure 6).

Another example, as shown in figure 7 promotes subsequent transmission after pre-emption and performs simulations to compare CBG-based and Pre-empted-resource-based transmission. A subsequent transmission is defined as the transmission (initial or repetition) of resources after initial transmission of a scheduled TB but before first Ack/Nack feedback. The initial subsequent transmission is then the case-2 where resources 2 and 4 were completely punctured. The repetition subsequent transmission refers to the case-3 where resources 2 and 3 were partially punctured or interfered during initial transmission. In the comparison system level simulations, an Uplink Pilot Time (UPT) gain between 10-15% can be provided.

In case CBG-level retransmission is configured, the most straightforward way for CBG-based HARQ-ACK feedback is to have one bit per CBG to denote ACK or NACK of the CBG as a whole. However, there is a number of drawbacks of this design for pre-empted transmission. These drawbacks include the following. If a pre-emption indication is configured, the HARQ operation is performed without taking into account this information. The result is that, when even a single CB is not decoded successfully due to pre-emption, HARQ-ACK feedback for a pre-empted CBG is a NACK even if the pre-emption is partial from the CBG point of view. Then, the spectral efficiency (SE) can be very low, especially when CBG size is configured to be relatively high, resulting to the similar problematic case experienced in LTE with 1-bit TB-level HARQ-ACK feedback. It is also possible that the CBG size configuration from gNB might be a slow process, for example if performed via Radio Resource Control (RRC). In that case, it will not be possible to take into account the sporadic URLLC traffic, hence, gNB will not be able to perfectly align URLLC transmissions with CBG configuration, leading often to partially punctured CBGs.

An extreme solution to overcome such low SE issue may be to report Ack/Nack per CB. Although this practice will notify most accurately every erroneous CB to gNB, as previously mentioned, it would be highly inefficient. The following table shows the trends for HARQ-ACK payload increase when number of failed CB indexes needs to be reported.

TBS in number of CBs	10	20	30	40	50	60
Bits needed to report one CB index	4	5	5	6	6	6
Bits needed to report two CB indexes	6	8	9	10	11	11

Therefore, HARQ-ACK feedback for pre-emption should be designed to: take into account the pre-emption indication, in order to be able to obtain the throughput benefits of finer-than-CBG-level retransmission, while at the same time keeping the low signalling advantages of CBG-level HARQ-ACK feedback.

It has been proposed to design the UE's HARQ-ACK feedback and gNB's HARQ retransmission based on the HARQ-ACK feedback by considering the effect of the pre-emption. This has been implemented by splitting CBs on critically impacted (by puncturing) and not-critically impacted CBs and generate HARQ-ACK feedback based on the CB-level CRCs of the not-critically impacted CBs as shown in figure 8. This splitting is based on whether it is expected that a CB can be decoded despite the pre-emption. This implementation has some very clear disadvantages. Firstly it does not address the CBG-based aspect directly (Only TB and CBs mentioned). Even if the proposed method is translated to CBG, e.g. if a TB in the solution is considered as a CBG, Ack/Nack feedback to gNB will not give any information on correct/erroneous CBs within a CBG. Further, if a CB in the solution is considered as a CBG, there is no adequate method proposed on how to cope with missed pre-emption indication at UE. The proposal also fails to address the requirement that there is a common understanding between UE and gNB on what can be considered as a critically impacted CBs. Even if a concise selection rule is selected for the eNB to denote a CB as critically impacted, a misunderstanding between UE and gNB on that aspect cannot be avoided if the pre-emption indication is missed at UE.

The above described examples, proposals and schemes are either inefficient or do not solve all the problems associated with CBG-based HARQ-ACK feedback for when pre-emption indication is used to notify a receiver of resources pre-empted during the transmission of some or all of a code block group or a transport block.

The present invention is seeking to solve at least some of the outstanding problems in this domain.

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 enabling access to services provided by a Radio Access Network between first and second wireless communications devices, the method comprising: wherein a HARQ-ACK feedback is generated at the second wireless communication device based on resources pre-empted during the transmission of a transport block from the first wireless communications device so that the second wireless communication device can monitor for pre-empted resources.

Preferably, common knowledge between the first and second wireless communications devices is taken into account by both devices based on a notification of pre-empted resources from the first wireless communications device.

Preferably, wherein one of the first and second wireless communication devices is configurable to generate HARQ-ACK feedback.

Preferably, wherein one of the first and second wireless communication devices is configurable to automatically monitor for the HARQ-ACK feedback from the other of the first and second wireless communication devices.

Preferably, the HARQ-ACK feedback comprises more than one bit for each CBG that is partially punctured.

Preferably, the HARQ-ACK feedback comprises more than one bit for the code blocks that are punctured.

Preferably, the HARQ-ACK feedback comprises more than one bit for those code blocks or CBGs that are not punctured.

Preferably, wherein the HARQ-ACK feedback comprises 1-bit for each CBG, and wherein an acknowledgment message is used to indicate correct decoding of non-punctured resource.

Preferably, the method includes a step of reporting on resources experiencing bursty interference.

Preferably, the second wireless communication device provides a puncturing indication receipt confirmation to the first wireless communications device.

Preferably, for a given TB in which one or more CBGs or Code blocks are corrupted due to puncturing; the second wireless communication device is capable of sending a feedback ACK or NACK for the whole TB.

Preferably, for a given CBG in which one or more Code blocks are corrupted due to puncturing and one or more code blocks are corrupted for another reason; the second wireless communication device is capable of sending a feedback NACK for the whole CBG.

Preferably, HARQ retransmission occurs based on the HARQ-ACK feedback using at least one of a different option; retransmission of only corrupted resources or not decoded CBs; regrouping of CBGs and retransmission of CBGs including corrupted CBs; or adaptation of partially punctured CBGs to include only not decoded CBs and retransmission of these CBGs.

Preferably, HARQ-ACK feedback comprises using at least one of a different PUCCH format; a different PUCCH resource; a different scrambling of Uplink Control Information bits; a different Cyclic Redundancy Check appended to UCI bits; or extra bits in a separate part of HARQ-ACK feedback, upon decoding.

Preferably, HARQ-ACK feedback includes a predetermined number of extra Ack/Nack bits containing information regarding punctured CBGs.

Preferably, the Radio Access Network is a New Radio/5G network.

According to a second aspect of the present invention there is provided a base station capable of performing the method of another aspect of the present invention.

According to a third aspect of the present invention there is provided a User equipment capable of performing the method of another aspect of the present invention.

According to a fourth aspect of the present 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 of another aspect of the present invention.

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 graph of signal to noise ratio (SNR) V Spectral efficiency, in accordance with the prior art;

Figure 2 is a simplified diagram showing part of an eMBB transmission that is punctured, in accordance with the prior art;

Figure 3 is a diagram showing CBGs to be mapped consecutively in time onto physical f/t resources, in accordance with the prior art;

Figure 4 is a diagram showing CBGs may be partially punctured, in accordance with the prior art;

Figure 5 is a diagram showing control signalling and feedback flow for pre-emption indication and CBG-based multi-bit HARQ-ACK feedback and retransmission, in accordance with the prior art;

Figure 6 is a simplified diagram showing 4-symbol URLLC puncturing on 14-symbol eMBB slots, in accordance with the prior art;

Figure 7 is diagram showing subsequent transmission after pre-emption, in accordance with the prior art;

Figure 8 is a proposed implementation to split CBs on critically impacted and not-critically impacted CBs, in accordance with the prior art;

Figure 9 is simple diagram of a scheme, according to an embodiment of the present invention;

Figure 10 is a diagram showing a scheme, dealing with a bursty interference, according to an embodiment of the present invention;

Figure 11 is a diagram showing CBG acknowledgements, according to an embodiment of the present invention;

Figure 12 is a diagram showing signalling for a scheme, according to an embodiment of the present invention; and

Figure 13, is a diagram showing a sub-options for a scheme, according to an embodiment of the present invention.

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.

The present invention relates to communication systems (e.g. 5G/NR, 4G/LTE) using HARQ feedback from UE to eNB in order to report ACK'ed or NACK'ed downlink data. The invention specifically targets the scenario of dynamically multiplexed services, i.e. when DL data of different transmission durations use the same resource, where system is configured to allow a transmission that is shorter in time to pre-empt a longer ongoing transmission. In that case, also a pre-emption indication may be configured to notify the UE (that is the intended recipient of the longer transmission, e.g. eMBB UE) of a pre-empted transmission. Bursty interference from shorter transmissions in neighbouring cells may also be apparent in such scenario.

The purpose of the invention is to provide an efficient mechanism for the eMBB UE to create a low size ACK/NACK payload according to the successful or unsuccessful decoding of received data and for eNB/gNB to determine the exact number of HARQ-ACK bits sent by the eMBB UE.

This invention discloses a new design of CBG-based HARQ-ACK feedback if pre-emption indication is used to notify a receiver of resources pre-empted during the transmission of a transport block. The proposed pre-emption-aware HARQ-ACK feedback takes into account the common knowledge, between gNB and UE, received from a pre-emption indication, and provides a low payload CBG-level feedback to gNB to acquire finer granularity knowledge of CBs that have been decoded

successfully. In addition, for a complete HARQ operation using the present invention it is possible for the gNB-UE common understanding on HARQ-ACK feedback size to be addressed. It is further possible to adjust to fall-back TB-level operation and to achieve a finer-than-CBG-level retransmission.

The proposed pre-emption-aware CBG-based HARQ-ACK feedback is able to obtain the benefits of finer-than-CBG-level retransmission which in turn can result in higher SE, and/or more robust retransmission which can lead to reduced latency due to multiple retransmissions for a TB. This is accomplished, while at the same time keeping the low signalling advantages of CBG-level HARQ-ACK feedback; instead of feeding back to gNB a large CB pass/fail bitmap, UE can only report an enhanced (with re-purposed bits or just few extra bits) low-payload CBG pass/fail bitmap along with information (if needed) whether it successfully received the pre-emption indication.

The embodiments of the invention will now be described in detail below. In accordance with a UE is configured to send a special HARQ-ACK feedback per partially punctured CBG when receiving pre-emption indication. This can be achieved in a number of different ways.

In a first example, more than one (e.g. 2) bit can be sent for every CBG that is partially punctured in order to give some more information regarding to which CBs UE was really able to decode within those CBGs. For fully punctured CBG, only NACK can be given using 1-bit. For example, with 2 bits, UE may notify the gNB if there was correct decoding within a CBG of: all the CBs; the group of non-punctured CBs; and the group of punctured CBs. This is shown in figure 9.

A first additional advantage of using more than one bit per punctured CBG, is the opportunity to notify decoding outcome on CBs experiencing bursty interference when both gNB and UE are aware and have common understanding of such interference. Consider for example a scenario, where a neighbouring cell (cell-B) also allows short URLLC transmissions which can result to bursty interference to eMBB transmission to UE in cell of interest (cell-A). If there is a way for gNB to notify UE in a timely manner about such transmissions occurring in neighbouring cells it is possible for UE to use the proposed pre-emption-aware CBG-based HARQ-ACK feedback to notify its gNB on decoding success of a group of CBs affected by such bursty interference. To implement this, gNBs may carry out some or all of the

following functions for example: Exchange neighbouring short transmission information (such as f/t resources used by URLLC on slot x) via an equivalent to LTE X1 interface; but in a faster, e.g. <4ms manner. Timing Advance (TA) information may be taken into account. The gNBs may signal to their UEs the f/t resources of bursty interference on previously received resources. In other words, they may be included in the pre-emption indication. .

It is possible that within a given CBG, there are simultaneously some CBs corrupted due to puncturing, and some CBs corrupted due to other reasons (e.g. low channel quality). In that case, UE should feedback NACK for the whole CBG (both for punctured part and the rest of CBG). Compared to the conventional 1-bit A/N per-CBG approach, a disadvantage of the preemption-aware HARQ-ACK feedback embodiment above is the unnecessary higher UL control signalling. A solution in that case could be to adopt a 'CBG-level fall-back operation' for such CBGs, meaning that in that case the UE could choose (or be configured by gNB) to indicate no awareness of puncturing to gNB and just feedback a NACK using 1-bit as normal. In a second example, only 1-bit can be sent per CBG, but ACK can be re-purposed to mean "ACK = Non-punctured area is decoded correctly" when e.g. puncturing indication is configured to a UE. This is shown in figure 11.

One disadvantage of the 1-bit alternative compared with the 2-bit alternative is that it is necessary to assume all the CBs associated with the punctured area erroneously decoded even if there are partially pre-empted CBs that have been successfully decoded at UE. This may lead to some DL data throughput loss which can be considerable for example in case the partially punctured CBG consists of a few (or even just one in extreme case) robustly transmitted CBs. The 1-bit example combines with a mechanism for UE to confirm receipt of puncturing indication as will be described below. Thus, it is possible for the gNB to be certain of what exact resources need retransmission and protect from having to retransmitting the whole CBG in case the pre-emption indication is missed at UE (thus, NACK is sent for the punctured CBG instead of ACK). In addition, a (possibly ambiguous and not fitting for all scenarios) selection rule for critically impacted CBs is not needed. It should be sufficient to bundle/categorise CBs within a CBG as (wholly or partially) punctured or non-punctured.

In a third example, a predetermined number of extra Ack/Nack bits containing useful information regarding punctured CBGs is added to the CGB-level HARQ-ACK feedback. This alternative will increase the control overhead even when no puncturing occurs, but it does not require an extra mechanism to tackle gNB-UE misunderstanding on HARQ-ACK codebook.

When CBG-level retransmission is not configured, a TB-level HARQ-ACK feedback (1 Ack/Nack bit per TB, as in LTE) is expected. When CBG-level retransmission is configured it should also be possible to fall-back to TB-level retransmission, especially when the UE identifies there are no or too many errors throughout the whole TB.

It is envisaged that when CBG-based retransmission is configured, TB-level HARQ-ACK feedback is supported and at least the following options can be considered for down-selection in RAN1#90. Option 1: add 1 bit onto CBG-level HARQ-ACK bits; Option 2: use all NACK of CBG-level HARQ-ACK bits; and Option 3: use different PUCCH formats or PUCCH resources. Any of the three options can be adapted to work with the proposed pre-emption-aware CBG-level feedback.

An alternative way would be to denote a TB-level fall-back operation using one of the methods we propose below for UE confirming to gNB of puncturing indication receipt. In that case, considering for example the proposed explicit signalling method, an extra bit in the 1st part of HARQ-ACK feedback, upon decoding, may indicate to gNB if a CBG- or TB- level Ack/Nack has been provided within the Uplink Control Information (UCI). The alternative implicit signalling methods (e.g. scrambling of the UCI bits or CRC) could also be considered.

It is also necessary to consider what the implication of having more than one bit per punctured CBG is and what happens when a puncturing indication is sent by gNB but missed by UE. In this case, understanding between gNB and UE on transmitted HARQ-ACK codebook will be corrupted since gNB will translate a larger number of UCI bits received as HARQ-ACK feedback while that will not be the case. Generally, reliability of HARQ-ACK feedback needs to be high as there will be undetectable error events and it will take the upper layer a long time to detect the error and arrange retransmission.

It is expected that the Puncturing indication transmission via Downlink Control Information (DCI) will be designed to be quite robust. However, if the UE fails to receive it there will be a misunderstanding of HARQ-ACK codebook. In addition, there will be effects from misunderstanding of other UCI types. When this situation is considered to be an important problem, the present invention can introduce a Puncturing indication confirmation mechanism. An additional indication in Uplink (UL), may for example notify gNB if UE has received correctly the pre-emption indication sent in DCI.

This UL indication for puncturing indication receipt confirmation may be separately coded within UCI bits by explicit signalling. For example, one solution would be to split HARQ-ACK feedback in two steps and send the confirmation within the first step. HARQ-ACK feedback may thus consist of two fields, wherein the first field includes the pre-emption receipt indication and the second field comprises the actual HARQ-ACK feedback bits. Figure 11 illustrates such an example.

An alternative solution may be that the UL indication for puncturing indication receipt confirmation is sent via implicit signalling. For example a different PUCCH format, PUCCH resource, scrambling of the UCI bits or CRC may be used to denote if the HARQ-ACK feedback has been constructed by the UE considering a received puncturing indication or not. Also, in case polar coding is used for the UCI (e.g. for larger size UCI), it may be possible to use an implicit indication of the pre-emption indication receipt confirmation through a specific sequence scrambled with one or more reliable data bits of the polar code.

Considering the proposed pre-emption-aware HARQ-ACK feedback, there are at least three options for HARQ retransmission that may be adopted and lead to a beneficial performance.

Option-1 is a resource/CB-based retransmission, which is based on the proposed HARQ-ACK feedback. The retransmission may only include pre-empted resources, as these are indicated by pre-emption indication. Alternative, both gNB and UE can know exactly which CBs within a CBG have been punctured, and retransmit just those ones. Figure 12 illustrates the saving in retransmission from the above sub-options for a CBG of size 3 where just 1 CB is partially punctured.

Option-2 is a CBG-based retransmission with adapted CBG-size. This solution may perform retransmission with finer level that the CBG-level of the initial transmission, while maintaining the CBG-level retransmission operation. This would allow the adjustment/regrouping of CBGs within a TB between initial transmission and retransmission to occur. For example, consider a TB of 2 CBGs (CBG-1 and CBG-2) of size 30 CBs each. When the middle 20 CBs are punctured due to URLLC pre-emption, after gNB receives the proposed pre-emption-aware CBG-level HARQ-ACK feedback, the CBGs may be reconfigured. For example, via the DCI scheduling of the retransmission, the gNB may reconfigure the CBGs to UE to be: CBG-1, which includes the first 20 CBs decoded correctly, CBG-2, which includes the last 20 CBs decoded correctly, CBG-3, which includes the punctured CBs punctured. Then, the gNB can retransmit only CBG-3 to UE. In case DCI scheduling and retransmission with regrouped CBGs is missed, however, an additional mechanism may be needed to avoid any confusion.

In some relevant situations, it may be assumed that for initial transmission and retransmission, each CBG of a TB has the same set of CB(s). When this is the case, option 2 is not possible to implement. Option-3 is a robust CBG-based retransmission while keeping the same set of CBs per CBG. In other words, there is no regrouping of the CBGs entailed, but for retransmission of a partially punctured CBG, gNB would only include in the respective transmission resources the CBs that are actually punctured. Therefore, with this option it is possible to use fewer resources for retransmission or even spread the CBs on the retransmission resources to make the retransmission more robust. With the proposed pre-emption-aware CBG-level HARQ-ACK feedback, gNB and UE will have common understanding of what is actually missing at the UE for a punctured CBG. So, for example, if only 10 of the initially 30 transmitted CBs in CBG-1 have been punctured, gNB can retransmit CBG-1 with lower coding rate (e.g. using a simple rate matching mechanism) by including only the punctured CBs. The UE will be only expecting the missing CBs from CBG-1 and may perform HARQ combining respectively, only for the partially punctured CBs, using for example the knowledge from puncturing indication and stored information from initial transmission in its soft buffer.

Although DL data transmission with UL feedback for NR is considered in the discussion above, this invention can be used by many different transmissions. These

include by way of example, the following. LTE: sTTI transmissions, in which an equivalent to URLLC topic is being defined currently. The pre-emption-based multiplexing of the present invention is likely to be relevant. UL data transmission with DL feedback may also be able to benefit from the present invention. In a similar way to DL, the HARQ feedback proposal may apply to UL HARQ when pre-emption or bursty interference is experienced in UL transmissions.

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.

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.

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.

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.

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. In addition, 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 enabling access to services provided by a Radio Access Network between first and second wireless communications devices, the method comprising: wherein a HARQ-ACK feedback is generated at the second wireless communication device based on resources pre-empted during the transmission of a transport block from the first wireless communications device so that the second wireless communication device can monitor for pre-empted resources.

2. The method of claim 1, wherein common knowledge between the first and second wireless communications devices is taken into account by both devices based on a notification of pre-empted resources from the first wireless communications device.

3. The method of claim 1 or claim 2, wherein one of the first and second wireless communication devices is configurable to generate HARQ-ACK feedback.

4. The method of claim 3, wherein one of the first and second wireless communication devices is configurable to automatically monitor for the HARQ-ACK feedback from the other of the first and second wireless communication devices.

5. The method of any preceding claim, wherein the HARQ-ACK feedback comprises more than one bit for each CBG that is partially punctured.

6. The method of any preceding claim, wherein the HARQ-ACK feedback comprises more than one bit for the code blocks that are punctured.

7. The method of any preceding claim, wherein the HARQ-ACK feedback comprises more than one bit for those code blocks or CBGs that are not punctured.

8. The method of any of claims 1 to 4, wherein the HARQ-ACK feedback comprises 1-bit for each CBG, and wherein an acknowledgment message is used to indicate correct decoding of non-punctured resource.

9. The method of any preceding claim, including a step of reporting on resources experiencing bursty interference.

10. The method of any preceding claim, wherein the second wireless communication device provides a puncturing indication receipt confirmation to the first wireless communications device.

11. The method of any preceding claim, wherein for a given TB in which one or more CBGs or Code blocks are corrupted due to puncturing; the second wireless communication device is capable of sending a feedback ACK or NACK for the whole TB.

12. The method of any preceding claim, wherein for a given CBG in which one or more Code blocks are corrupted due to puncturing and one or more code blocks are corrupted for another reason; the second wireless communication device is capable of sending a feedback NACK for the whole CBG.

13. The method of any preceding claim, wherein HARQ retransmission occurs based on the HARQ-ACK feedback using at least one of a different option; retransmission of only corrupted resources or not decoded CBs; regrouping of CBGs and retransmission of CBGs including corrupted CBs; or adaptation of partially punctured CBGs to include only not decoded CBs and retransmission of these CBGs.

14. The method of claim 10 or claim 11, wherein HARQ-ACK feedback comprises using at least one of a different PUCCH format; a different PUCCH resource; a different scrambling of Uplink Control Information bits; a different Cyclic Redundancy Check appended to UCI bits; or extra bits in a separate part of HARQ-ACK feedback, upon decoding.

15. The method any preceding claim, wherein HARQ-ACK feedback includes a predetermined number of extra Ack/Nack bits containing information regarding punctured CBGs.

16. The method of any preceding claim, wherein the Radio Access Network is a New Radio/5G network.

17. A user equipment, UE, apparatus comprising a processor, a storage unit and a communications interface, wherein the processor unit, storage unit,

and communications interface are configured to perform the method as claimed in any one of claims 1-16.

18. A base station, BS, apparatus comprising a processor, a storage unit and a communications interface, wherein the processor unit, storage unit, and communications interface are configured to perform the method as claimed in any one of claims 1-16

19. 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 1-16.

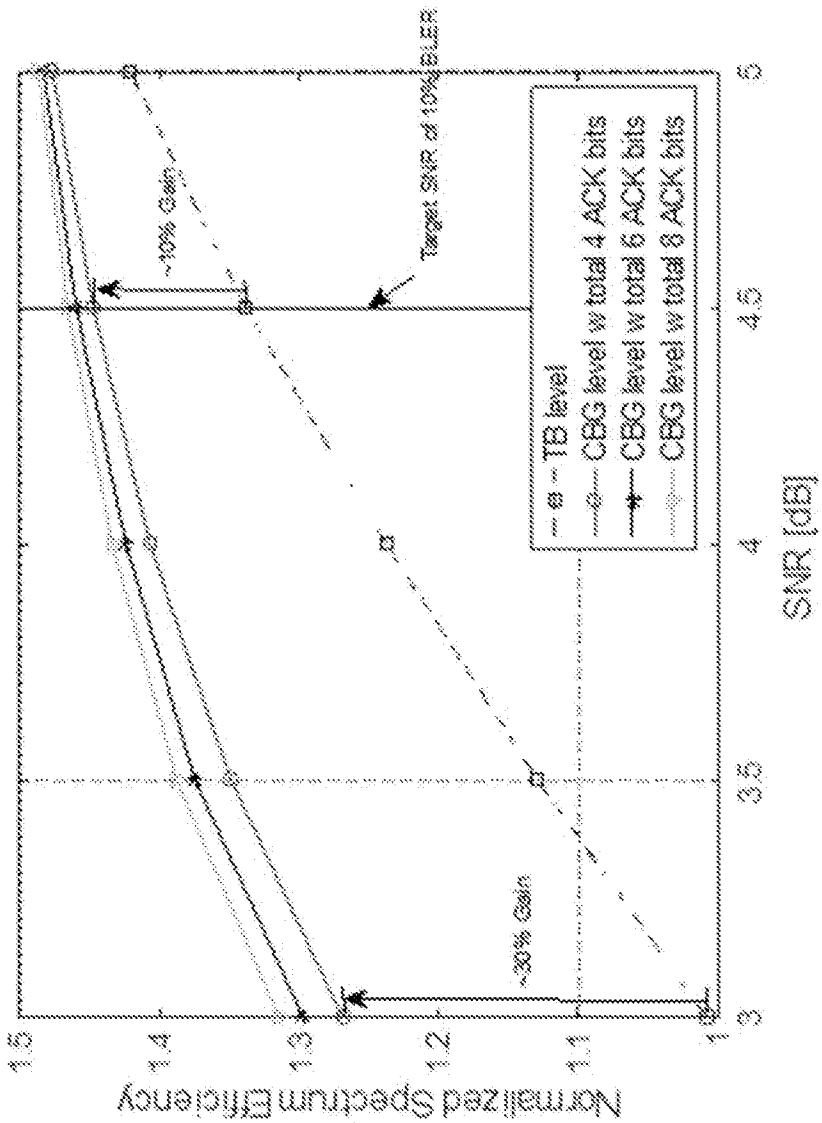

Normalized Spectrum Efficiency
SNR [dB]
Target SNR at 10% BLER
~10% Gain
~30% Gain
TB level
CBG level w total 4 ACK bits
CBG level w total 6 ACK bits
CBG level w total 8 ACK bits

Figure 1

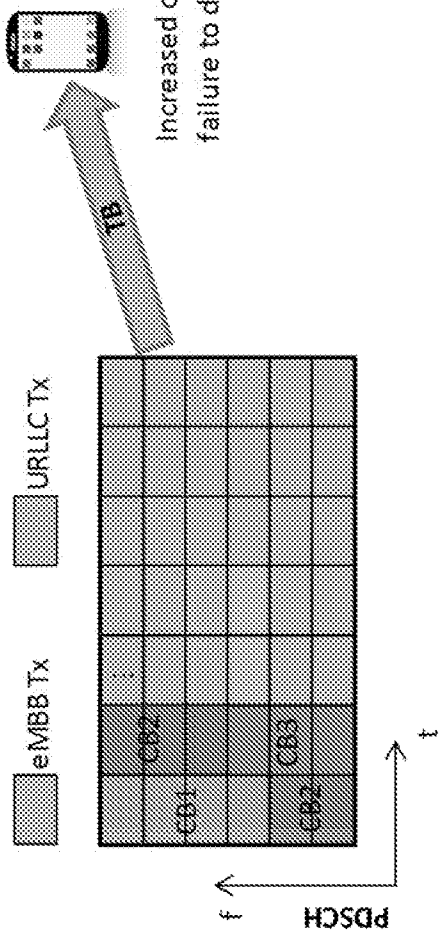

Increased chance for eMBB UE
failure to decode its TB
TB
URLLC Tx
eMBB Tx
CB1
CB2
CB3
CB4
PDSCH
f
t

Figure 2

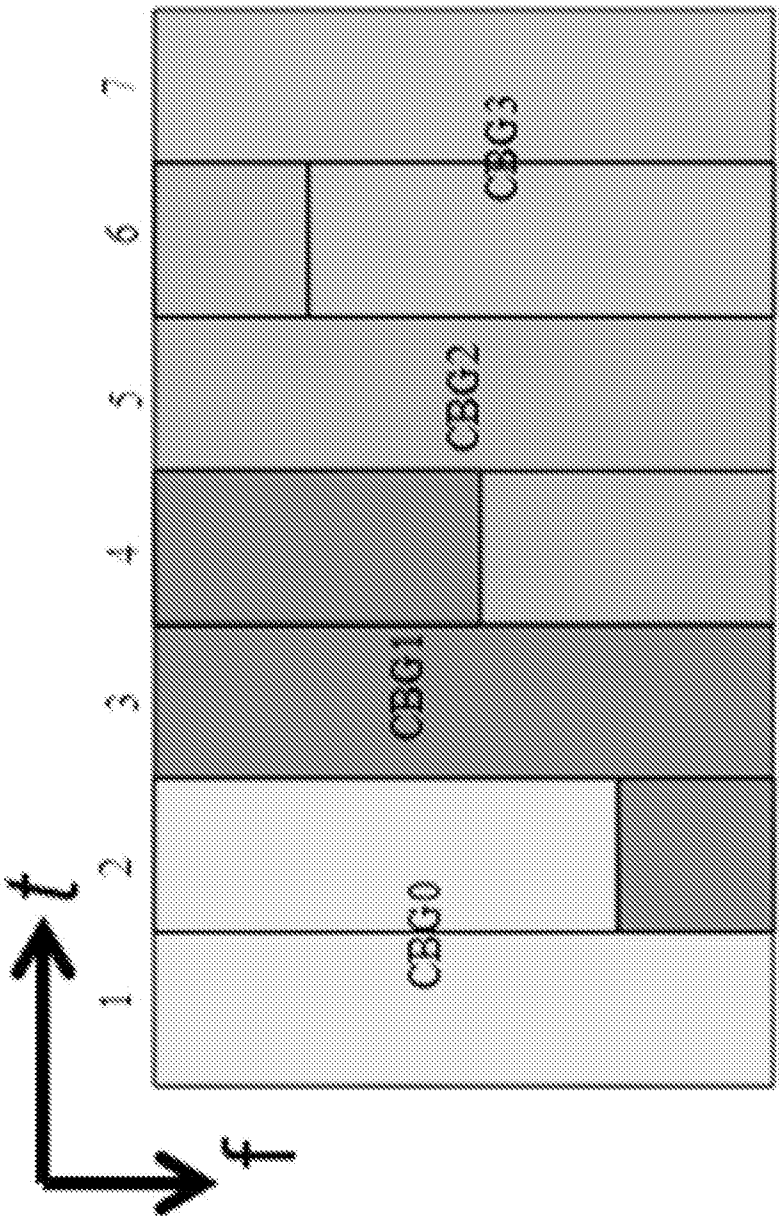


Figure 3

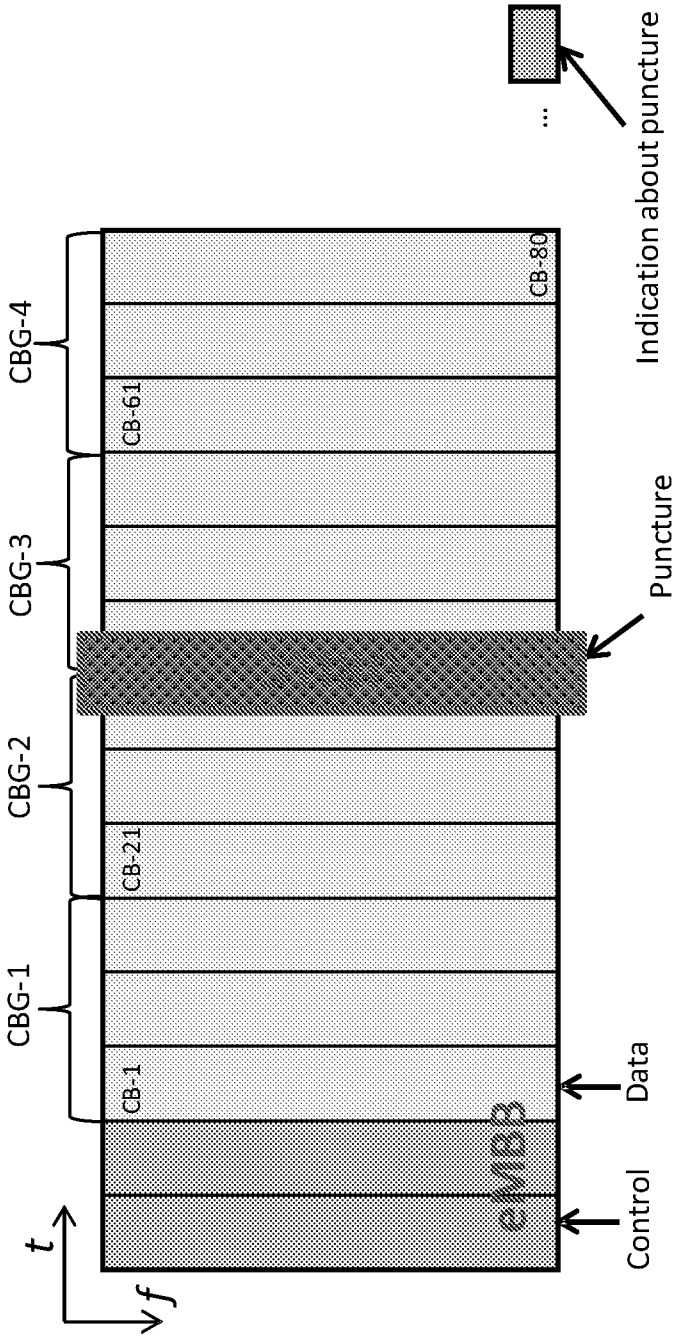


Figure 4

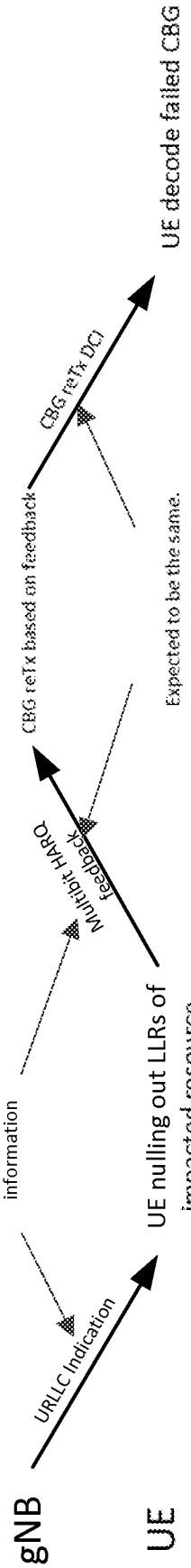


Figure 5

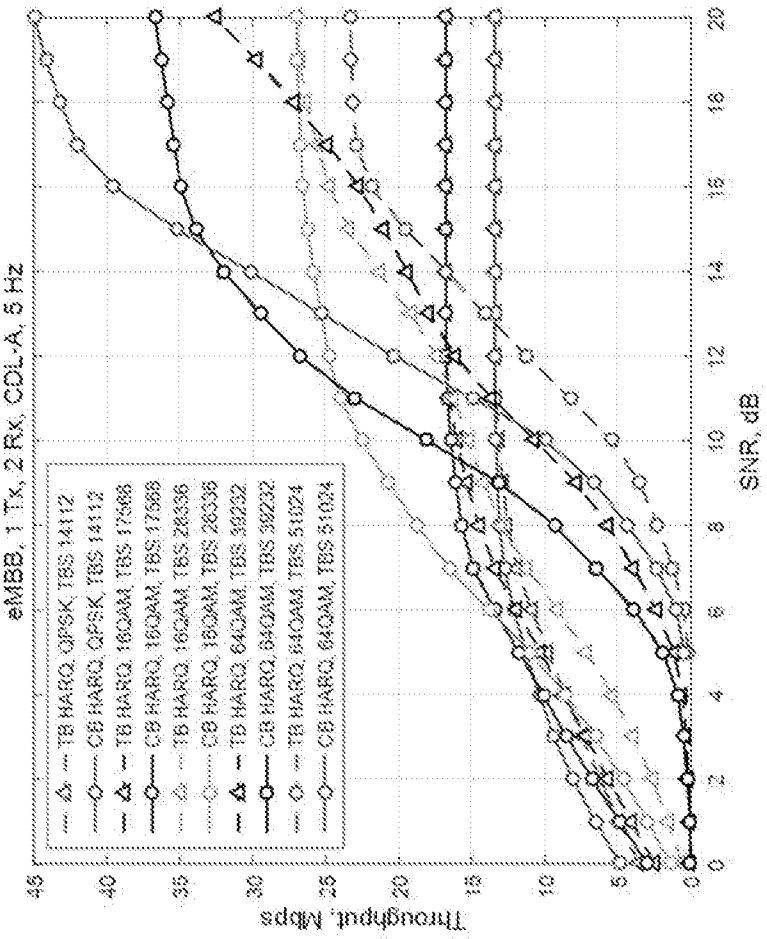
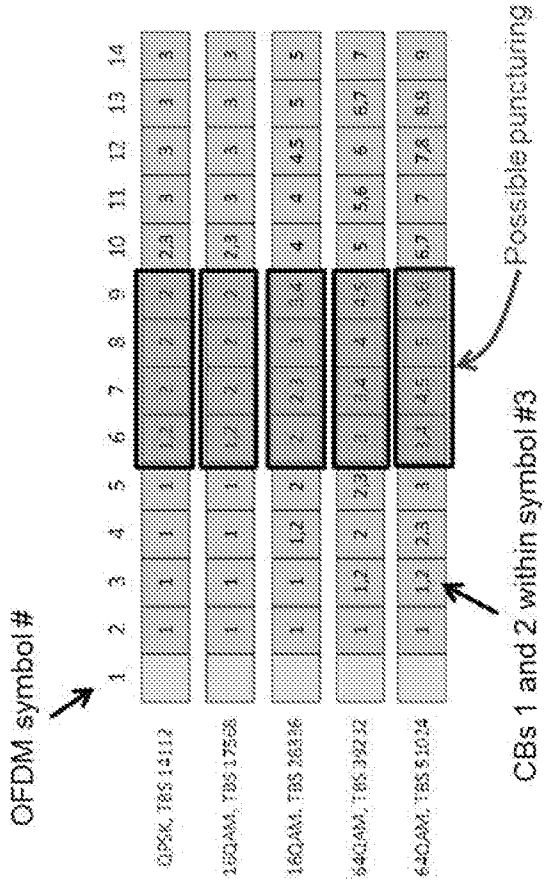

eMBB, 1 Tx, 2 Rx, CDL-A, 5 Hz
Throughput, Mbps
SNR, dB
TB HARQ, QPSK, TBS 14112
CB HARQ, QPSK, TBS 14112
TB HARQ, 16QAM, TBS 17568
CB HARQ, 16QAM, TBS 17568
TB HARQ, 16QAM, TBS 28336
CB HARQ, 16QAM, TBS 28336
TB HARQ, 64QAM, TBS 39232
CB HARQ, 64QAM, TBS 39232
TB HARQ, 64QAM, TBS 51024
CB HARQ, 64QAM, TBS 51024

Figure 6


OFDM symbol #
QPSK, TBS 14112
16QAM, TBS 17568
16QAM, TBS 28336
64QAM, TBS 39232
64QAM, TBS 51024
CBs 1 and 2 within symbol #3
Possible puncturing

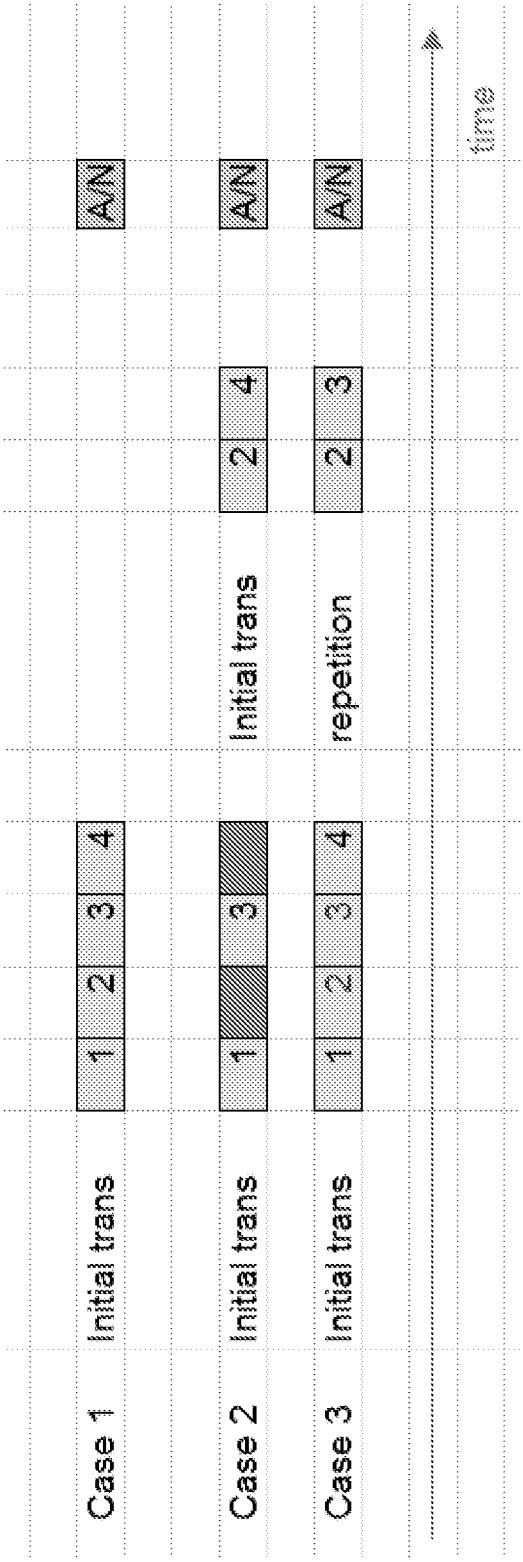

Case 1
Initial trans
1
2
3
4
A/N
Case 2
Initial trans
1
3
2
4
A/N
Case 3
Initial trans
1
2
3
4
repetition
2
3
A/N
time

Figure 7

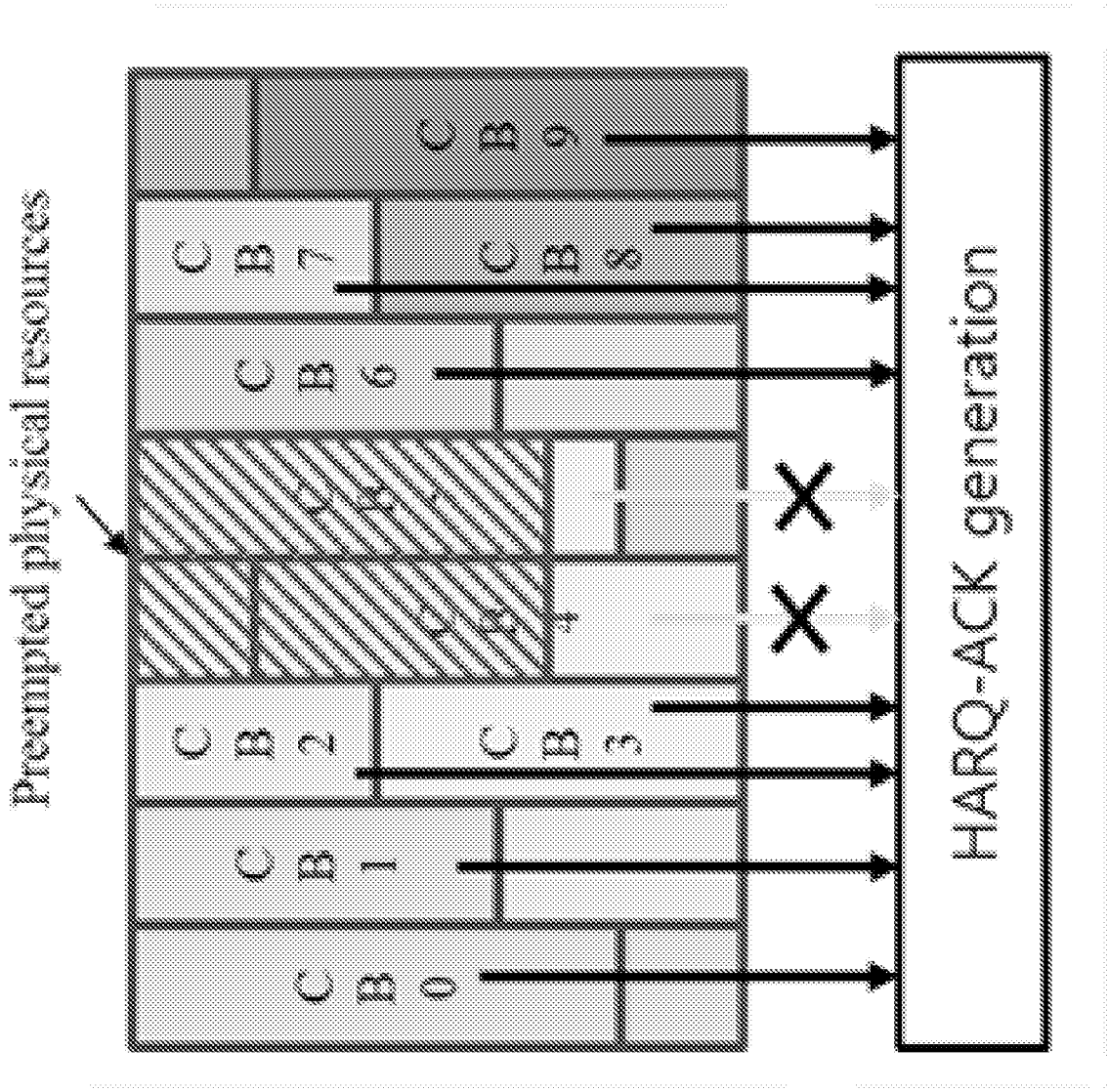

Preempted physical resources
C B 0
C B 1
C B 2
C B 3
C B 4
C B 5
C B 6
C B 7
C B 8
C B 9
HARQ-ACK generation

Figure 8

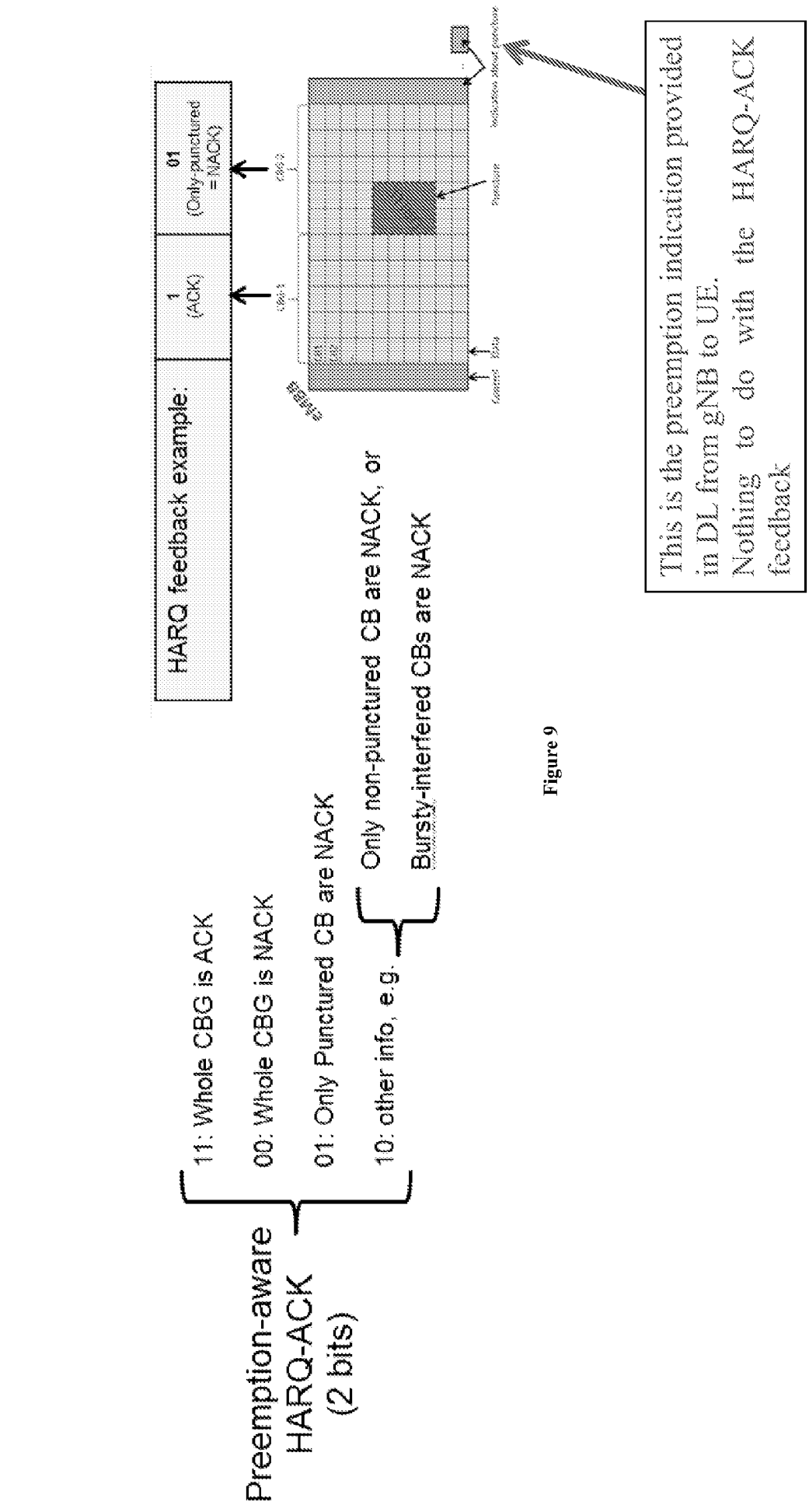

Preemption-aware HARQ-ACK (2 bits)
11: Whole CBG is ACK
00: Whole CBG is NACK
01: Only Punctured CB are NACK
10: other info, e.g.
Only non-punctured CB are NACK, or
Bursty-interfered CBs are NACK
HARQ feedback example:
1 (ACK)
01 (Only-punctured = NACK)
This is the preemption indication provided in DL from gNB to UE.
Nothing to do with the HARQ-ACK feedback

Figure 9

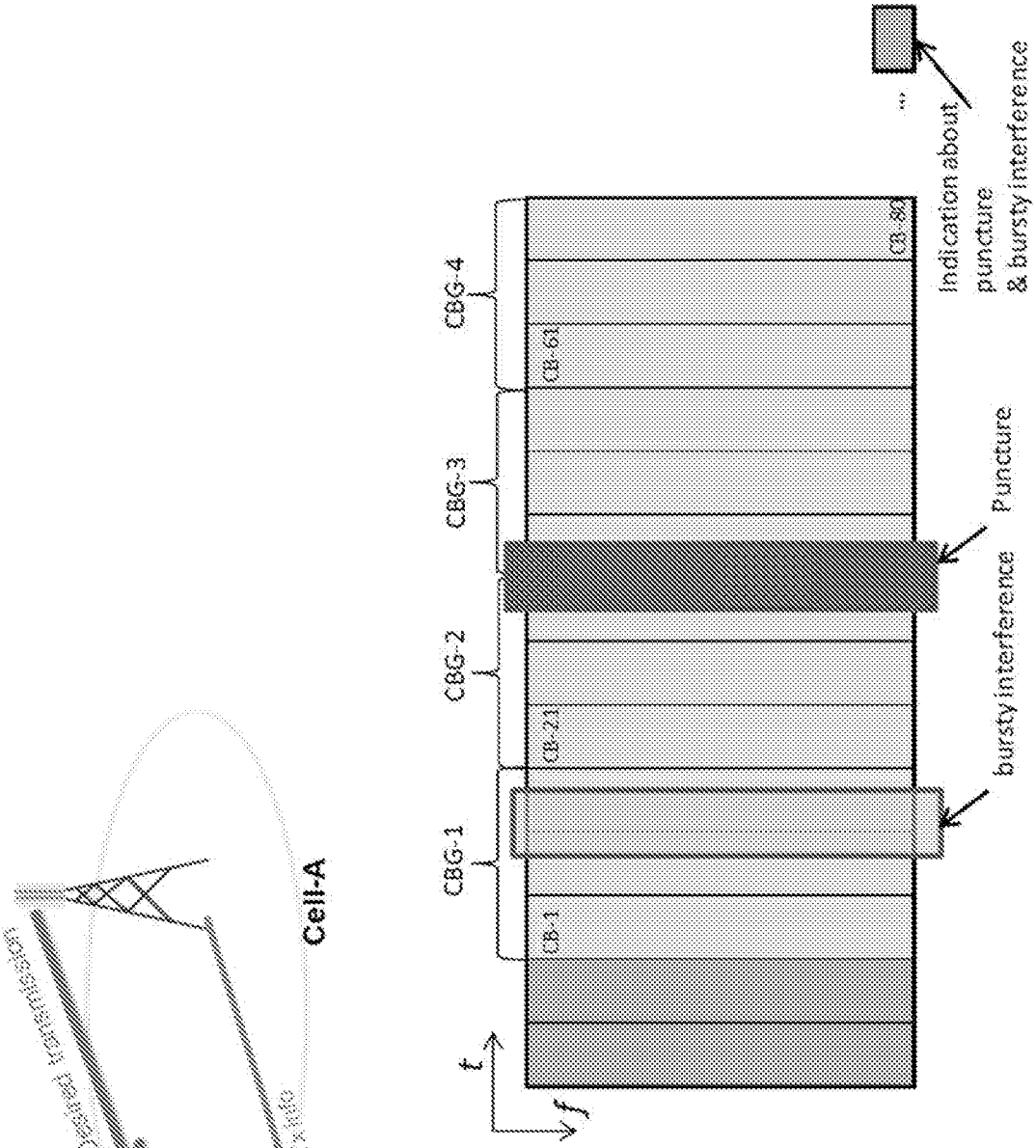

Cell-A
Cell-B
eMBB UE
URLLC UE
CBG-1
CBG-2
CBG-3
CBG-4
CB-1
CB-21
CB-61
CB-80
Puncture
bursty interference
Indication about
puncture
& bursty interference
t
f

Figure 10

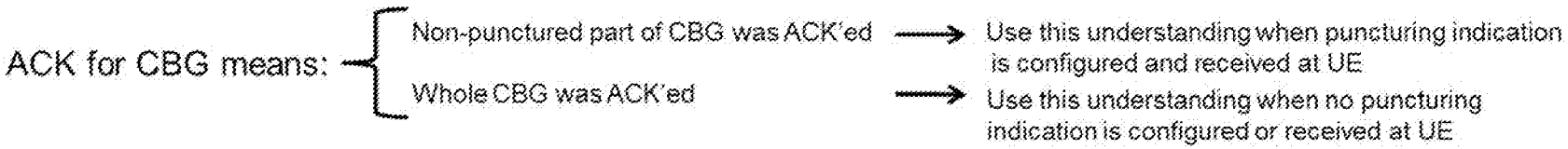


Figure 11

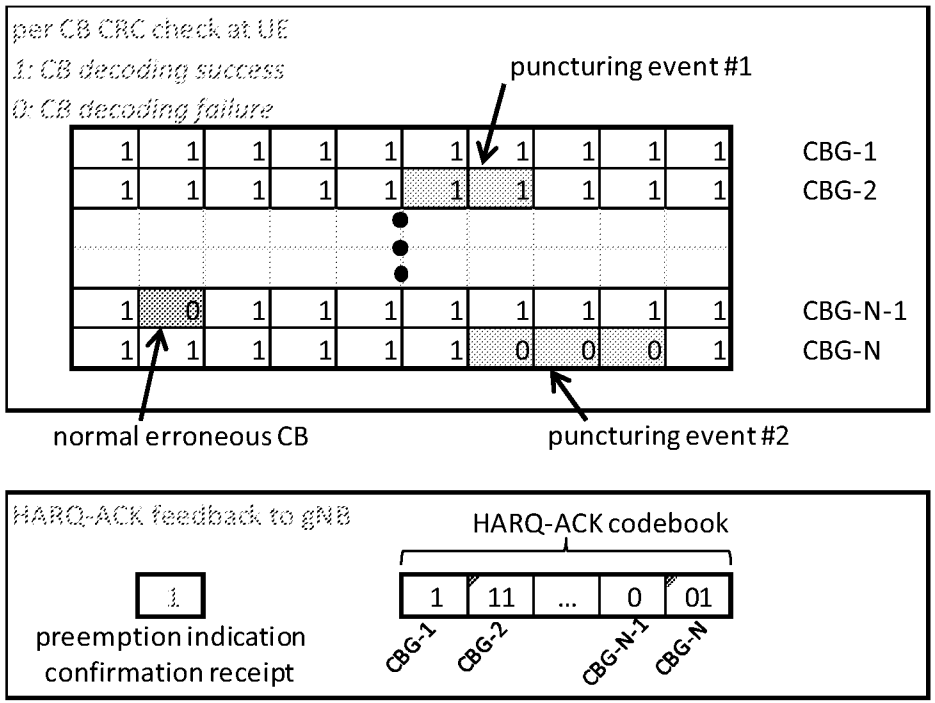


Figure 12

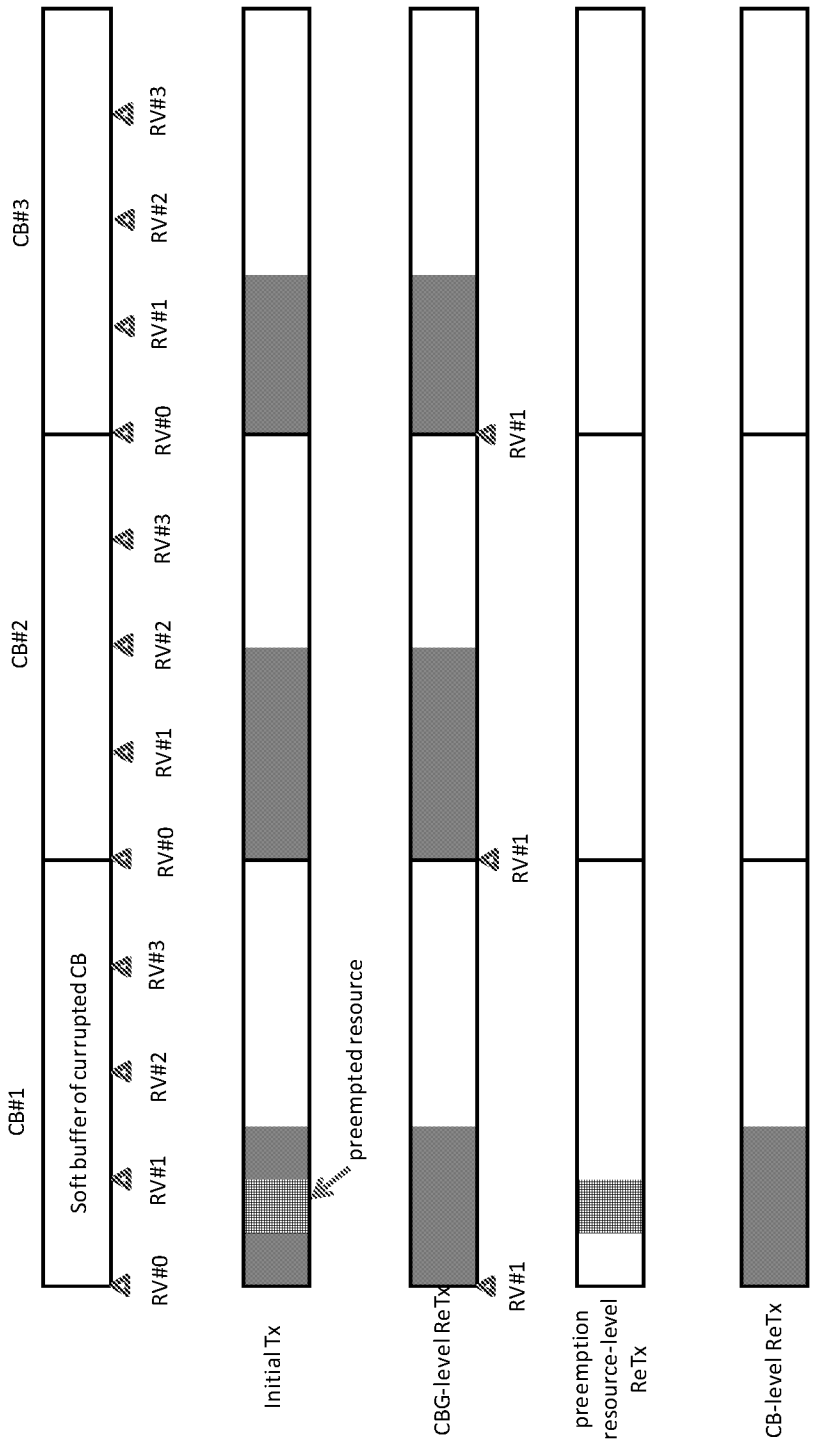

CB#1
CB#2
CB#3
Soft buffer of currupted CB
RV#0
RV#1
RV#2
RV#3
RV#0
RV#1
RV#2
RV#3
RV#0
RV#1
RV#2
RV#3
Initial Tx
preempted resource
CBG-level ReTx
RV#1
RV#1
preemption resource-level ReTx
CB-level ReTx

Figure 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/097916

A. CLASSIFICATION OF SUBJECT MATTER

H04W 72/04(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

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI; EPODOC; CNKI; CNPAT: HARQ, ACK, feedback, pre-empted, punctured, CBG,transport, block

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012243497 A1 (CHUNG JAE HOON ET AL.) 27 September 2012 (2012-09-27) description, paragraphs [0009]-[0075]	1-19
A	CN 102823179 A (LG ELECTRONICS INC.) 12 December 2012 (2012-12-12) the whole document	1-19
A	US 2003108027 A1 (SAMSUNG ELECTRONICS CO., LTD.) 12 June 2003 (2003-06-12) the whole document	1-19
A	WO 2017053948 A1 (IDAC HOLDINGS, INC.) 30 March 2017 (2017-03-30) the whole document	1-19

☐ 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
28 September 2018	**18 October 2018**

Name and mailing address of the ISA/CN	Authorized officer
STATE INTELLECTUAL PROPERTY OFFICE OF THE P.R.CHINA **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**LV,Yuan**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961640**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/097916

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2012243497	A1	27 September 2012	US	8848643	B2	30 September 2014
				WO	2011084020	A2	14 July 2011
				WO	2011084020	A3	08 December 2011
				CN	102714565	B	02 March 2016
				CN	102714565	A	03 October 2012
CN	102823179	A	12 December 2012	CN	102823179	B	08 July 2015
				US	2013016687	A1	17 January 2013
				WO	2011118943	A2	29 September 2011
				WO	2011118943	A3	15 December 2011
				US	8958380	B2	17 February 2015
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				GB	2384397	A	23 July 2003
				GB	2384397	B	31 March 2004
				DE	10255655	B4	22 April 2010
				US	7372842	B2	13 May 2008
				CN	1427636	A	02 July 2003
				KR	20030043426	A	02 June 2003
				DE	10255655	A1	28 August 2003
				GB	0227763	D0	08 January 2003
WO	2017053948	A1	30 March 2017	EP	3353926	A1	01 August 2018
				CN	108141316	A	08 June 2018