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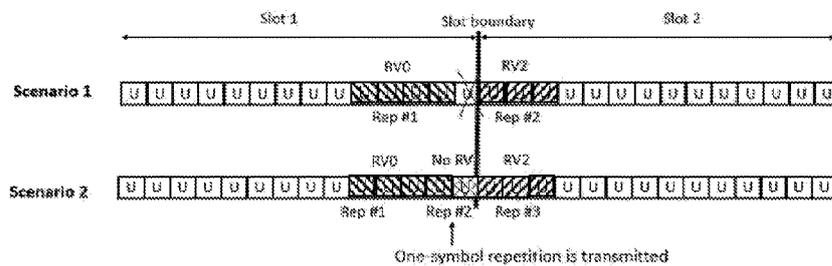


Fig. 7

(57) Abstract: A method of enhancing performance of a Physical Uplink Shared Channel, PUSCH, repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network is disclosed. The method is carried out by the UE and the method comprises: receiving scheduled resources and number of repetitions in the PUSCH transmission; receiving an indication of a process adopted on occurrence of a one-symbol repetition; executing a listen-before-talk procedure to acquire the PUSCH; proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; and executing, on occurrence of a one-symbol repetition and based on the indication, an additional listen-before-talk procedure in a time interval of the one-symbol repetition.



Performance Enhancement of PUSCH Repetition Method in Wireless Communication Systems

Technical Field

[1] The invention relates to methods of enhancing performance of a PUSCH repetition Type B method used for transmission of repetitions in a Physical Uplink Shared Channel (PUSCH) transmission by a User Equipment (UE) to a base station (gNB) of a wireless communications system, in licensed and unlicensed spectrum for Ultra-Reliable and Low-Latency Communications (URLLC) with strict requirements of latency and reliability.

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 and UE must compete with other devices for physical medium/resource access. For example, Wi-Fi, NR-U, and LAA may utilise the same physical resources.

[6] In order to share resources a Listen Before Talk (LBT) protocol is proposed in which a gNB or UE monitors the available resources and only commences a transmission if there is no conflict with another device already utilising the resources. Once an LBT process is successful (the resources are "won"), the gNB or UE gains access to the resources for up to the Maximum Channel Occupancy Time (MCOT) provided there is no interruption of transmissions for more than a pre-defined interval (for example 16 μ s).

[7] A trend in wireless communications is towards the provision of lower latency and higher reliability services. For example, NR is intended to support Ultra-reliable and low-latency communications (URLLC) and massive Machine-Type Communications (mMTC) are intended to provide low latency and high reliability for small packet sizes (typically 32 bytes). A user-plane

latency of 1ms has been proposed with a reliability of 99.99999%, and at the physical layer a packet loss rate of 10^{-5} or 10^{-6} has been proposed.

[8] After the transmitter of the node has gained access to the channel, the node is only allowed by regulation to transmit for up to a limited duration, the MCOT, and may choose to use a COT which is equal to or only part of the duration of the MCOT for one or more transmissions. To provide differentiation to channel access priorities based on the type of traffic served (e.g. VoIP, video, best effort, or background), four LBT priority classes are defined with different CWS and MCOT.

[9] The physical design of URLLC is challenging as two conflicting factors, reliability and latency, have to be addressed at the same time. For URLLC service requirements, the term reliability is generally defined as the success probability R of transmitting X bits within L seconds, where L is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface, at a certain channel quality Q (e.g., coverage-edge). The latency bound L includes transmission latency, processing latency, retransmission latency (if any), and queuing/scheduling latency (including scheduling request and grant reception if any). Spectral efficiency should also be considered when trying to achieve a reliability target.

[10] Regarding a reliability target for the URLLC scenario, NR defines a general URLLC reliability requirement for one transmission of a packet is 10^{-5} for 32 bytes with a user plane latency of 1ms. This URLLC reliability requirement has been updated to 10^{-6} for enhanced URLLC. This strict reliability requirement requires very careful design of transmit-receive techniques within a very low latency budget which can range between 0.5 to 1 msec.

[11] Developments in the physical design of URLLC to address the reliability and latency factors includes PUSCH enhancements. In uplink (UL) transmissions, one PUSCH transmission instance is not allowed to cross a slot boundary for both dynamic grant (DG) and configured grant (CG) PUSCH.

[12] To avoid sending a long PUSCH transmission across a slot boundary, the UE sends small PUSCH transmissions in several repetitions, which are scheduled by UL resource grant or radio resource control (RRC) in consecutive available transmission slots. This method is called PUSCH repetition Type A. The use of such PUSCH repetitions for one transport block (TB) reduces latency and increases reliability of PUSCH transmission, where a UE can be configured to transmit a number of repetitions across consecutive transmission slots without feedback. In the PUSCH repetition Type A method, each slot contains only one TB repetition and the time domain for the repetitions of the TB is the same in each slot.

[13] A new method, PUSCH repetition Type B, was developed to address issues of time gaps between repetitions in PUSCH repetition Type A method. In the PUSCH repetition Type B method, repetitions are carried out in consecutive mini-slots, so one slot might contain more than one repetition of a TB. However, the repetitions can be segmented into smaller repetitions due to a slot boundary, presence of DL symbols, presence of symbols in an invalid pattern.

[14] Use of the PUSCH comprises dynamic grant (DG) and configured grant (CG) of PUSCH resources. There are two types of CG configuration. In Type 1 CG, RRC signalling indicates the full time domain resource allocation including periodicity, offset, start symbol, length of PUSCH transmission and K repetitions over K slots/sub-slots (repK), without any layer 1 signalling as downlink control information (DCI). For type 2 CG, only periodicity and repK are given through RRC signalling. The other time domain resource allocation parameters are provided through DCI activation scrambled with CS-RNTI.

[15] In unlicensed spectrum use, a channel access procedure exists. A transmitter of a UE is required to execute a listen before talk (LBT) procedure to check availability of a channel before transmission. In UL DG transmission, a UE can access a channel according to Type 1 or Type 2 UL channel access defined by UL resource grant.

[16] In Type 1 UL channel access, a UE senses energy of a channel over a defer time duration. The length of the defer duration depends on channel access priority class, as shown in Figure 1 : $16 + 9 \cdot m_p$ (μs). If energy detection is below a threshold, the channel is considered as idle in the defer duration, otherwise the channel is busy. After sensing an idle channel in the defer duration, the UE senses the channel for additional slots. The number of additional slots (N) is chosen randomly from a uniform distribution between 0 and CW_p , the value of which depends on channel priority access class, again as shown in Figure 1. Each time the UE senses the idle channel in an additional slot, it decreases N by 1. When N reaches 0, the UE transmits data.

[17] In Type 2 UL channel access, a UE transmits data immediately after sensing the channel acquired by the gNB is idle within a duration of $16 \mu\text{s}$ (Type 2B) or $25 \mu\text{s}$ (Type 2A). If the gap between two UL transmissions is smaller than $16 \mu\text{s}$, the UE does not have to execute the LBT procedure before transmitting the second UL transmission.

[18] UL transmission of a TB is supported with multiple repetitions of the TB to achieve the strict URLLC requirements on reliability. The time domain resource assignment (TDRA) field in the DCI indicates the resource for the first "nominal" repetition of the TB. The time domain resources for the remaining repetitions of the TB are derived based at least on the resources for the first TB repetition and UL/DL direction of symbols. The dynamic indication of the number of repetitions for DG is jointly coded with start and length indicator values (SLIV), which indicate the start symbol and the length of PUSCH transmission, in a TDRA table using DCI formats 0_1 and 0_2, by adding an additional column for the number of repetitions in the TDRA table. The maximum TDRA table size is increased to 64. For CG PUSCH transmission, if the number of repetitions is not included in the TDRA table, it is provided by RRC parameter $repK$.

[19] The number of the PUSCH repetitions represents the "nominal" number of repetitions. The actual number of repetitions might be bigger than the nominal number. If a nominal repetition encounters a slot boundary or the presence of DL symbols in a time division duplex (TDD) configuration, this repetition is fragmented into multiple actual repetitions.

[20] In unlicensed spectrum, the interruption in UL transmission of the TB repetitions causes LBT overhead. Figure 2 shows two scenarios of UL transmission in a TDD configuration. In both scenarios, the UE is scheduled by the gNB to transmit four nominal TB repetitions using the PUSCH repetition Type B method (DG or CG transmission). The time window within which valid symbols are used for transmission is $K \times L$ where K is four nominal repetitions and L is the length of a nominal repetition. Before the transmission, the UE must execute a LBT Type 1 procedure to acquire the channel and it is allowed to use this channel for a Channel Occupancy Time (COT) duration.

[21] In scenario 1 of Figure 2, there are four consecutive UL sub-slots so the UE can transmit the whole four repetitions without an interruption, after successful execution of a LBT Type 1 procedure. However, in scenario 2, the UL transmission is interrupted because of the presence of DL symbols in the middle of the second repetition. The UE cannot transmit UL data in a DL transmission occasion, so the second repetition is fragmented into two actual repetitions. With SCS from 15 kHz to 120 kHz and a sub-slot of 2, 4, 7 symbols, the time length of the DL sub-slot is larger than $16 \mu\text{s}$. In some cases, DL symbols are configured in a semi-static way in advance. If the gNB does not have DL data to transmit at those semi-static DL symbols, there will be a gap between two UL bursts. When the gap between two UL transmissions is larger than $16 \mu\text{s}$, due to

the presence of the empty semi-static DL symbols, the UE must execute an additional LBT procedure, a LBT Type 2 procedure, to continue to transmit the remaining repetitions in the UE-initiated COT. This COT is initiated by the LBT Type 1 procedure before the first repetition. The additional LBT Type 2 procedure consumes at least 25 μ s. This LBT procedure time can be more than 25 μ s if the channel is busy. The time window $K \times L$ is fixed, so an increase of LBT procedure time reduces the time for data transmission. The UE transmits less data in the repetition than is configured, which causes a decrease of reliability. In this scenario 2 of Figure 2, the UL repetitions must be scheduled in the UL transmission resources, segmented by the DL sub-slots, to satisfy the URLLC latency budget of 1 ms, the UL repetition transmission cannot wait for the next available four consecutive UL sub-slots for transmission of all of the repetitions.

[22] In licensed spectrum, the presence of DL symbols in the middle of PUSCH repetitions also reduces the number of valid symbols for PUSCH transmission that the UE can use in the time window $K \times L$. This affects the reliability of UL transmission of a TB.

[23] Gaps in the transmission of UL TB repetitions is also caused by encountering a slot boundary, even if a nominal repetition is fragmented into two actual repetitions. In scenario 2 of Figure 3, two repetitions of a TB are scheduled using the PUSCH repetition Type B method. Each repetition has four symbols. After the first repetition, the second repetition is fragmented by the slot boundary between slot 1 and slot 2. There is one symbol of the second repetition in slot 1 and 3 symbols in slot 2. However, repetitions having a single symbol are not transmitted. Thus, the UE does not transmit a repetition in the last symbol of slot 1 so this symbol is empty. The UE only starts to transmit the second repetition from the first symbol of slot 2. This creates a gap of one symbol between the two repetitions. With SCS from 15 kHz to 60 kHz, the length of a symbol is larger than 16 μ s. Therefore, in unlicensed spectrum, at least, execution of a LBT procedure of 25 μ s is needed before the transmission of the second repetition. This causes LBT overhead and reduces the time interval in which the UE can transmit the second repetition.

Summary

[24] 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.

[25] There is provided a method of enhancing performance of a physical uplink shared channel (PUSCH) repetition Type B method used for repetitions in a PUSCH transmission by a user equipment (UE) to a base station gNB of a wireless communications network, the method comprising: scheduling by the gNB resources and number of repetitions in the PUSCH transmission; establishing by the gNB an indication of listen before talk (LBT) process adopted on interruption of the PUSCH transmission; receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission; receiving by the UE the indication of LBT process adopted on interruption of the PUSCH transmission; executing by the UE a LBT procedure to acquire the PUSCH; proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of LBT process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method without execution of an additional LBT procedure.

[26] The method may be used for PUSCH transmissions of ultra-reliable, low-latency communications (URLLC) having high priority.

[27] The indication of LBT process may be adopted on interruption of the PUSCH transmission comprises an explicit signal for the indication.

[28] The explicit signal for the indication may comprise any of a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE, an additional parameter in radio resource control (RRC) signalling.

[29] The indication of LBT process may be adopted on interruption of the PUSCH transmission comprises an implicit signal for the indication.

[30] The implicit signal for the indication may comprise a high value of a priority index for the PUSCH transmission.

[31] The method may be used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of DL symbols during transmission of the repetitions and the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of DL symbols comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the gNB to the UE, an additional parameter in RRC signalling.

[32] The method may be used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of invalid symbols during transmission of the repetitions and the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of invalid symbols comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the gNB to the UE, an additional parameter in RRC signalling.

[33] The method may be used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by a slot boundary producing a one-symbol repetition and the indication of LBT process adopted on interruption of the PUSCH transmission caused by a slot boundary producing a one-symbol repetition comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the gNB to the UE, an additional parameter in RRC signalling.

[34] The indication of LBT process may be adopted on interruption of the PUSCH transmission comprises an explicit signal comprising a value of a first additional bit in DCI for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a value of a second additional bit in DCI for interruption caused by a slot boundary producing a one-symbol repetition.

[35] The indication of LBT process may be adopted on interruption of the PUSCH transmission comprises an explicit signal comprising a first additional parameter in RRC signalling for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a second additional parameter in RRC signalling for interruption caused by a slot boundary producing a one-symbol repetition.

[36] There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising: scheduling by the gNB resources and number of repetitions in the PUSCH transmission; establishing by the gNB an indication of transmission process adopted on occurrence of a one-symbol repetition; receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission; receiving by the UE the indication of transmission process adopted on occurrence of a one-symbol repetition; executing by the UE a LBT procedure to acquire the PUSCH; proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; on occurrence of a one-symbol repetition, the indication of transmission process adopted on occurrence of a one-symbol repetition causing the UE to proceed with transmission of the one-

symbol repetition and further repetitions in the PUSCH transmission using the PUSCH repetition Type B method.

[37] The method may be used for PUSCH transmissions of URLLC having high priority.

[38] The one-symbol repetition may contain DMRS.

[39] The indication of transmission process may be adopted on occurrence of a one-symbol repetition comprises an explicit signal for the indication.

[40] The explicit signal for the indication may comprise any of a value of an additional bit in DCI sent by the gNB to the UE, an additional parameter in RRC signalling.

[41] The indication transmission process may be adopted on occurrence of a one-symbol repetition comprises an implicit signal for the indication comprising a high value of a priority index for the PUSCH transmission.

[42] There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising: scheduling by the gNB resources and number of repetitions in the PUSCH transmission; establishing by the gNB an indication of process adopted on occurrence of a one-symbol repetition; receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission; receiving by the UE the indication of process adopted on occurrence of a one-symbol repetition; executing by the UE a LBT procedure to acquire the PUSCH; proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; on occurrence of a one-symbol repetition, the indication of process adopted on occurrence of a one-symbol repetition causing the UE to execute an additional LBT procedure in a time interval of the one-symbol repetition.

[43] The time interval of the one-symbol repetition and the additional LBT procedure may equal a time interval for one OFDM symbol and the time interval of the additional LBT procedure may be configured to fit within the time interval for the one OFDM symbol.

[44] There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising: scheduling by the gNB resources, number of repetitions and DL symbols in the PUSCH transmission; establishing by the gNB an indication of transmission process adopted on interruption of the PUSCH transmission; receiving by the UE the scheduled resources, number of repetitions and DL symbols in the PUSCH transmission; receiving by the UE the indication of transmission process adopted on interruption of the PUSCH transmission; executing by the UE a LBT procedure to acquire the PUSCH (in unlicensed spectrum); proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to switch at least some of the DL symbols to UL symbols and proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of the UL symbols.

[45] The indication of transmission process may be adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the gNB has no DL data to transmit by means of the DL symbols.

[46] The indication of transmission process may be adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the gNB has DL

data to transmit by means of the DL symbols and UL data of the repetitions has higher priority than the DL data.

[47] For DG transmission, the indication of transmission process may be adopted on interruption of the PUSCH transmission comprises any of a dynamic SFI signal sent to the UE, a value of an additional bit of a DCI for UL resource grant, a high value of a priority index for the PUSCH transmission.

[48] For CG transmission, the indication of transmission process may be adopted on interruption of the PUSCH transmission comprises any of a high value of a priority index for the PUSCH transmission, a DCI format 2_0.

[49] There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising: scheduling by the gNB resources and number of repetitions in the PUSCH transmission; establishing by the gNB an indication of transmission process adopted on interruption of the PUSCH transmission; receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission; receiving by the UE the indication of transmission process adopted on interruption of the PUSCH transmission; executing by the UE a LBT procedure to acquire the PUSCH (in unlicensed spectrum); proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of semi-static flexible symbols in the scheduled resource.

[50] There is provided a UE configured to perform any of the methods described above.

[51] There is provided a non-transitory computer readable medium storing instruction which when executed by a computer carry out any of the method described above. 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

[52] 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.

[53] Figure 1 shows channel access priority classes for UL.

[54] Figure 2 shows two scenarios of UL transmission in a TDD configuration.

[55] Figure 3 shows interruption in the transmission of UL repetitions due to a slot boundary.

[56] Figure 4 shows a schematic diagram of three base stations forming a cellular network.

[57] Figure 5 shows interruption of transmission of repetitions in a PUSCH transmission caused by DL symbols.

[58] Figure 6 shows interruption of transmission of repetitions in a PUSCH transmission caused by a slot boundary producing a one-symbol repetition.

[59] Figure 7 shows transmission of a one-symbol repetition.

[60] Figure 8 shows switching of DL symbols to UL symbols for use in the transmission of repetitions in a PUSCH transmission.

Detailed description of the preferred embodiments

[61] 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.

[62] Figure 4 shows a schematic diagram of three base stations (for example, eNB or gNBs depending on the particular cellular standard and terminology) forming a cellular network. Typically, each of the base stations will be deployed by one cellular network operator to provide geographic coverage for UEs in the area. The base stations form a Radio Area Network (RAN). Each base station provides wireless coverage for UEs in its area or cell. The base stations are interconnected via the X2 interface and are connected to the core network via the S1 interface. As will be appreciated only basic details are shown for the purposes of exemplifying the key features of a cellular network.

[63] The base stations each comprise hardware and software to implement the RAN's functionality, including communications with the core network and other base stations, carriage of control and data signals between the core network and UEs, and maintaining wireless communications with UEs associated with each base station. The core network comprises hardware and software to implement the network functionality, such as overall network management and control, and routing of calls and data.

[64] According to a first embodiment of the invention, a method is provided of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising scheduling by the gNB resources and number of repetitions in the PUSCH transmission, establishing by the gNB an indication of LBT process adopted on interruption of the PUSCH transmission, receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission, receiving by the UE the indication of LBT process adopted on interruption of the PUSCH transmission, executing by the UE a LBT procedure to acquire the PUSCH, proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method, when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of LBT process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method without execution of an additional LBT procedure.

[65] The method is used for PUSCH transmissions having high priority such as URLLC.

[66] The indication of LBT process adopted on interruption of the PUSCH transmission comprises an explicit signal for the indication.

[67] The explicit signal for the indication comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. In dynamic grant (DG) of PUSCH resources the additional bit is added to the DCI used for UL resource grant. In configured grant (CG) Type 2 of PUSCH resources the additional bit is added to the DCI to activate a CG configuration.

[68] Alternatively, the explicit signal for the indication comprises an additional parameter in radio resource control (RRC) signalling. This allows the design of the DCI to be unchanged. This

embodiment of the method is applicable to both DG and CG transmission, especially CG Type 1 transmission this is configured by the RRC without any DCI.

[69] In an alternative embodiment of the method, the indication of LBT process adopted on interruption of the PUSCH transmission comprises an implicit signal for the indication.

[70] The implicit signal for the indication comprises a high value of a priority index for the PUSCH transmission. For DG transmission, the high value of the priority index for the PUSCH transmission is indicated by a 1 bit priority field in the DCI for the UL resource grant. For CG transmission, the high value of the priority index for the PUSCH transmission is indicated by a RRC parameter or an activation DCI.

[71] The method is used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of DL symbols during transmission of the repetitions.

[72] The explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of DL symbols comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of DL symbols comprises an additional parameter in radio resource control (RRC) signalling.

[73] Currently, in TDD configuration, DL symbols may be configured in a semi-static way in advance. If the gNB does not have DL data to transmit at those semi-static DL symbols, there will be a transmission interruption or gap between transmission of repetitions before the empty DL symbols and transmission of repetitions after the empty DL symbols. A repetition may be segmented into two repetitions due to the empty semi-static DL symbols. If the transmission gap is bigger than 16 μ s, the UE must execute an additional LBT procedure before continuing transmission of the repetitions. The gap of 16 μ s is a value defined by the current standard. If the value of the gap is changed by the future standards, the method is still applicable.

[74] The invention sends an indication of LBT process adopted on interruption of the PUSCH transmission from the gNB to the UE. The LBT process causes the UE to proceed with transmission of the repetitions after the interruption of their transmission caused by the presence of DL symbols without execution of the additional LBT procedure. This is shown in scenario 2 of Figure 5, when transmission of a repetition is segmented into transmission of two repetitions due to empty semi-static DL symbols, the UE proceeds with transmission of Rep 3 without execution of the LBT procedure.

[75] The method is used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of invalid symbols during transmission of the repetitions.

[76] The explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of invalid symbols comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by the presence of invalid symbols comprises an additional parameter in radio resource control (RRC) signalling.

[77] The presence of invalid symbols is indicated by an *InvalidSymbolPattern* parameter. The *InvalidSymbolPattern* parameter may be a RRC parameter and/or an activation DCI parameter. Configuration and activation of the *InvalidSymbolPattern* parameter causes interruption of the PUSCH transmission, especially for CG transmission, as the gNB cannot predict arriving data at the UE for the whole active time of the CG configuration and cannot avoid conflict between invalid symbols and UL PUSCH transmission.

[78] The principle of the method may be extended to DL transmission in TDD configuration. If a DL transmission with high priority is segmented by UL symbols, the gNB carries out LBT process where it does not do an additional LBT procedure before resuming the DL transmission in case the UL symbols are empty.

[79] The method is used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by a slot boundary producing a one-symbol repetition.

[80] The explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by a slot boundary producing a one-symbol repetition comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. This can be applied to DG transmission and CG Type 2 transmission. Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by a slot boundary producing a one-symbol repetition comprises an additional parameter in radio resource control (RRC) signalling. This can be applied to DG transmission and CG Type 1 and Type 2 transmission.

[81] Currently, when repetitions are transmitted, if a repetition is fragmented into two repetitions by a slot boundary and one repetition has only one symbol, the one-symbol repetition is not transmitted. This creates an interruption in the UL PUSCH transmission and requires execution of an additional LBT procedure after the interruption. This, in turn, causes latency in unlicensed spectrum.

[82] When the gNB schedules resources and the number of repetitions to the UE, the gNB knows about the generation of one-symbol repetitions by the location of resources of the repetitions with respect to the slot boundaries. The gNB therefore knows about interruption of the transmission of repetitions in the PUSCH transmission and sends an indication of LBT process adopted on interruption of the PUSCH transmission to the UE. This causes the UE to proceed with transmission of the repetitions after the interruption of their transmission caused by a slot boundary producing a one-symbol repetition without execution of the additional LBT procedure. This is illustrated in Figure 6.

[83] Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by any of the presence of DL symbols, the presence of invalid symbols, a slot boundary producing a one-symbol repetition comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission caused by any of the presence of DL symbols, the presence of invalid symbols, a slot boundary producing a one-symbol repetition comprises an additional parameter in radio resource control (RRC) signalling.

[84] Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission comprises a value of a first additional bit in downlink control information (DCI) for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a value of a second additional bit in downlink control information (DCI) for interruption caused by a slot boundary producing a one-symbol repetition sent by the gNB to the UE. Alternatively, the explicit signal for the indication of LBT process adopted on interruption of the PUSCH transmission comprises a first additional parameter in radio resource control (RRC) signalling for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a second additional parameter in radio resource control (RRC) signalling for interruption caused by a slot boundary producing a one-symbol repetition sent by the gNB to the UE.

[85] In the first embodiment of the invention, execution of an additional LBT procedure is not required, i.e. is skipped, after an interruption in transmission of repetitions in the PUSCH transmission, due to any of the DL symbols or invalid symbols or a slot boundary. This happens when the PUSCH repetitions carry URLLC transport blocks having strict reliability and latency requirements. The LBT-skip indication signal is indicated by the gNB to the UE by using an additional bit in DCI, RRC or an association with the priority index in the DCI. This embodiment is most suitable for unlicensed spectrum.

[86] According to a second embodiment of the invention, a method is provided of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising scheduling by the gNB resources and number of repetitions in the PUSCH transmission, establishing by the gNB an indication of transmission process adopted on occurrence of a one-symbol repetition, receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission, receiving by the UE the indication of transmission process adopted on occurrence of a one-symbol repetition, executing by the UE a LBT procedure to acquire the PUSCH, proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method, on occurrence of a one-symbol repetition, the indication of transmission process adopted on occurrence of a one-symbol repetition causing the UE to proceed with transmission of the one-symbol repetition and further repetitions in the PUSCH transmission using the PUSCH repetition Type B method.

[87] Interruption of transmission of the repetitions in the PUSCH transmission due to occurrence of a one-symbol repetition is therefore avoided. The UE transmits the one-symbol repetition so the transmission of repetitions in the PUSCH transmission is continuous. Execution of a LBT procedure after occurrence of a one-symbol repetition is not required. This is shown in Figure 7. Transmission by the UE of the one-symbol repetition keeps the PUSCH resource and the UE can therefore transmit immediately further repetitions in the PUSCH transmission.

[88] The method of the second aspect of the invention is used for PUSCH transmissions having high priority such as URLLC.

[89] The one-symbol repetition contains a signal to ensure a continuous transmission among the repetitions. One of the signals that can be used in the one-symbol repetition is DMRS. The transmitted DMRS one-symbol repetition is not taken account in the calculation of an RV sequence of the repetitions.

[90] The transmission of DMRS one-symbol repetitions provides the UE with an opportunity to perform channel estimation and improves the performance of high priority UL transmission. As the DMRS one-symbol repetition does not contain data, it is not taken into account in the calculation of an RV sequence of the repetitions. In other words, the DMRS one-symbol repetition is transmitted but is not considered as an actual repetition.

[91] The indication of transmission process adopted on occurrence of a one-symbol repetition comprises an explicit signal for the indication.

[92] The explicit signal for the indication comprises a value of an additional bit in downlink control information (DCI) sent by the gNB to the UE. Alternatively, the explicit signal for the indication comprises an additional parameter in radio resource control (RRC) signalling.

[93] In UL DG transmission, the indication comprises a value of an additional bit in downlink control information (DCI) for UL resource grant. The value of the additional bit causes the UE to transmit a signal such as DMRS in the one-symbol repetition. In UL Type 1 CG transmission, the indication comprises an additional parameter in radio resource control (RRC) signalling. The

value of the additional parameter causes the UE to transmit a signal such as DMRS in the one-symbol repetition. In UL Type 2 CG transmission, the indication comprises an additional bit in an activation downlink control information (DCI). The value of the additional bit causes the UE to transmit a signal such as DMRS in the one-symbol repetition.

[94] In an alternative embodiment of the method, the indication transmission process adopted on occurrence of a one-symbol repetition comprises an implicit signal for the indication.

[95] The implicit signal for the indication comprises a high value of a priority index for the PUSCH transmission. For DG transmission, the high value of the priority index for the PUSCH transmission is indicated by a 1 bit priority field in the DCI for the UL resource grant. For CG transmission, the high value of the priority index for the PUSCH transmission is indicated by a RRC parameter or an activation DCI.

[96] According to a third embodiment of the invention, a method is provided of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising scheduling by the gNB resources and number of repetitions in the PUSCH transmission, establishing by the gNB an indication of process adopted on occurrence of a one-symbol repetition, receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission, receiving by the UE the indication of process adopted on occurrence of a one-symbol repetition, executing by the UE a LBT procedure to acquire the PUSCH, proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method, on occurrence of a one-symbol repetition, the indication of process adopted on occurrence of a one-symbol repetition causing the UE to execute an additional LBT procedure in a time interval of the one-symbol repetition.

[97] The time interval of the one-symbol repetition and the additional LBT procedure equals a time interval for one OFDM symbol. The time between the end of the additional LBT procedure and the beginning of the next repetition transmission is less than 16 μ s. The time interval of the additional LBT procedure is configured to fit within the time interval for the one OFDM symbol. The time interval of the additional LBT procedure is a function of sub-carrier spacing (SCS) which is pre-configured between the gNB and the UE.

[98] According to a fourth embodiment of the invention, a method is provided of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising scheduling by the gNB resources, number of repetitions and DL symbols in the PUSCH transmission, establishing by the gNB an indication of transmission process adopted on interruption of the PUSCH transmission, receiving by the UE the scheduled resources, number of repetitions and DL symbols in the PUSCH transmission, receiving by the UE the indication of transmission process adopted on interruption of the PUSCH transmission, executing by the UE a LBT procedure to acquire the PUSCH (in unlicensed spectrum), proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method, when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to switch at least some of the DL symbols to UL symbols and proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of the UL symbols.

[99] Currently, in TDD configuration, DL symbols can be configured in a semi-static way so that the gNB can transmit DL data (using PDCCH, PDSCH, SSB). Due to time constraint, the gNB may also schedule PUSCH transmission with repetitions that are segmented by semi-static DL

symbols. This causes interruption of the transmission of the repetitions in the PUSCH transmission segmentation of the PUSCH repetitions. This occurs even if the gNB has no DL data to transmit using the semi-static DL symbols in the PUSCH transmission. This is shown in scenario 1 of Figure 8. The DL symbols are scheduled in a semi-static way in advance, so the gNB does not know whether it has DL data to transmit using the semi-static DL symbols.

[100] The indication of transmission process adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the gNB has no DL data to transmit by means of the DL symbols.

[101] When the gNB schedules the repetitions in the PUSCH transmission, if it recognizes that it does not have DL data to transmit by means of the DL symbols, it causes the UE to switch all of the (empty) semi-static DL symbols to UL symbols. This is shown in scenario 2 of Figure 8, which shows transmission in unlicensed spectrum. There are two benefits of the DL to UL symbol switching: 1) the UE can transmit PUSCH repetitions without interruption or segmentation, so that the valid symbols for UL transmission is ensured to be $K \times L$, and 2) there is no execution of an additional LBT procedure due to the interruption. Switching of the empty semi-static DL symbols to UL symbols is also applied to the PUSCH repetitions in licensed spectrum, so that the UE can transmit all repetitions as configured in the time window to guarantee reliability.

[102] The indication of transmission process adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the gNB has DL data to transmit by means of the DL symbols and UL data of the repetitions has higher priority than the DL data.

[103] When the gNB has DL data to transmit by means of the semi-static DL symbols, if the UL data has higher priority than the DL data, the gNB causes the UE to switch the semi-static DL symbols to UL symbols and delays DL data transmission to a next available occasion so that the UE can transmit continuous high priority UL data.

[104] Switching of the DL symbols to UL symbols is applied to both DG and CG transmission.

[105] For DG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises a dynamic SFI signal sent to the UE. The dynamic SFI signal is a DCI format 2_0.

[106] Alternatively, for DG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises a value of an additional bit of a DCI for UL resource grant.

[107] Alternatively, for DG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises a high value of a priority index for the PUSCH transmission. For DG transmission, the high value of the priority index for the PUSCH transmission is indicated by a 1 bit priority field in the DCI for the UL resource grant. For CG transmission, the high value of the priority index for the PUSCH transmission is indicated by a RRC parameter or an activation DCI.

[108] For CG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises a dynamic SFI signal. The dynamic SFI signal may be a DCI format 2_0.

[109] The gNB can periodically send the DCI format 2_0. The period of sending the DCI format 2_0 depends on priority of the CG configurations, the arrival rate of UL data at the UE using the configurations and the arrival rate of DL data at the gNB.

[110] This method can be extended to switch semi-static UL symbols to DL symbols. The gNB can then switch semi-static UL symbols to DL symbols for use in DL transmission. This is useful when the gNB has a high arrival rate of URLLC DL data and needs to use the switched symbols to meet URLLC requirements for DL transmission. The gNB sends a dynamic SFI signal to notify the UE to switch the semi-static UL symbols to DL symbols, so that the UE decodes DL transmission in these symbols instead of transmitting UL data.

[111] In this aspect of the invention, DL symbols in the middle of URLLC PUSCH repetitions that cause interruption of transmission of repetitions are switched to UL symbols using a dynamic signal (an additional bit in DCI, RRC or an association with priority index in DCI/RRC) from the gNB. The interruption of the URLLC PUSCH repetitions is eliminated, so LBT overhead in unlicensed spectrum is also eliminated to reduce latency. Moreover, in both licensed and unlicensed spectrum, the UE can guarantee transmission of the repetitions as configured in the scheduled time window to achieve reliability requirements.

[112] According to a fifth embodiment of the invention, a method is provided of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a gNB of a wireless communications network, the method comprising scheduling by the gNB resources and number of repetitions in the PUSCH transmission, establishing by the gNB an indication of transmission process adopted on interruption of the PUSCH transmission, receiving by the UE the scheduled resources and number of repetitions in the PUSCH transmission, receiving by the UE the indication of transmission process adopted on interruption of the PUSCH transmission, executing by the UE a LBT procedure to acquire the PUSCH (in unlicensed spectrum), proceeding by the UE with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method, when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of semi-static flexible symbols in the scheduled resource.

[113] For CG transmission in licensed and unlicensed spectrum, if dynamic SFI is configured but the UE cannot decode the DCI format 2_0 indicating the SFI due to channel condition, the UE uses semi-static flexible symbols in the scheduled resource as UL symbols to transmit the repetitions without any interruption. In other words, a repetition is not fragmented around the semi-static flexible symbols or dropped because of conflict with the semi-static flexible symbols. Therefore, in unlicensed spectrum, execution of an additional LBT procedure is not required during the transmission of the PUSCH repetitions. Moreover, in both licensed and unlicensed spectrum, the configured number of repetitions is ensured.

[114] The various embodiments of the invention have the following advantages: reduction of LBT latency, increase in the time that the UE transmits data, increase in the UL transmission reliability, elimination of the gap between repetition transmissions, avoidance of dropping of CG PUSCH repetitions in the case of conflict with semi-static flexible symbols.

[115] 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.

[116] 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.

[117] 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.

[118] 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.

[119] 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.

[120] 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.

[121] 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.

[122] 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.

[123] 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.

[124] 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.

[125] 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.

[126] 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.

[127] 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.

[128] 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.

[129] 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 enhancing performance of a Physical Uplink Shared Channel, PUSCH, repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method carried out by the UE and the method comprising:
 - receiving scheduled resources and number of repetitions in the PUSCH transmission;
 - receiving an indication of a process adopted on occurrence of a one-symbol repetition;
 - executing a listen-before-talk procedure to acquire the PUSCH;
 - proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method; and
 - executing, on occurrence of a one-symbol repetition and based on the indication, an additional listen-before-talk procedure in a time interval of the one-symbol repetition.
2. The method of claim 1, wherein the time interval of the one-symbol repetition and the additional listen-before-talk procedure equal a time interval for one OFDM symbol.
3. The method of claim 2, wherein the time interval of the additional listen-before-talk procedure is configured to fit within the time interval for the one OFDM symbol.
4. The method of any preceding claim, wherein the PUSCH transmission is a PUSCH transmission of ultra-reliable, low-latency communications (URLLC) having high priority.
5. The method of any preceding claim, wherein receiving the indication comprises receiving an explicit signal for the indication.
6. The method of claim 5, wherein the explicit signal for the indication comprises any of a value of an additional bit in downlink control information (DCI) sent by the base station to the UE, an additional parameter in radio resource control (RRC) signalling.
7. The method of any of claims 1 to 4, wherein receiving the indication comprises receiving an implicit signal for the indication.
8. The method of claim 7, wherein the implicit signal for the indication comprises a high value of a priority index for the PUSCH transmission.
9. A UE comprising a processor arranged to perform the method of any one of claims 1 to 8.

10. A non-transitory computer readable medium storing instructions, which when executed by a computer, perform the method of any one of claims 1 to 8.

11. A method of enhancing performance of a Physical Uplink Shared Channel, PUSCH, repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method comprising:

scheduling, by the base station, resources and number of repetitions in the PUSCH transmission;

establishing, by the base station, an indication of a process adopted on occurrence of a one-symbol repetition;

receiving, by the UE, the scheduled resources and number of repetitions in the PUSCH transmission;

receiving, by the UE, the indication of the process adopted on occurrence of a one-symbol repetition;

executing, by the UE, a listen-before-talk procedure to acquire the PUSCH; and

proceeding, by the UE, with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

wherein, on occurrence of a one-symbol repetition, the indication of the process adopted on occurrence of a one-symbol repetition causes the UE to execute an additional listen-before-talk procedure in a time interval of the one-symbol repetition.

12. A method of enhancing performance of a physical uplink shared channel, PUSCH, repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method carried out by the UE and the method comprising:

receiving scheduled resources and number of repetitions in the PUSCH transmission;

receiving an indication of listen-before-talk process adopted on interruption of the PUSCH transmission;

executing a listen-before-talk procedure to acquire the PUSCH; and

proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

wherein when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of listen-before-talk process adopted on interruption of the PUSCH transmission causes the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method without execution of an additional listen-before-talk procedure.

13. The method of claim 12, wherein the PUSCH transmission is a PUSCH transmission of ultra-reliable, low-latency communications (URLLC) having high priority.
14. The method of any of claims 12 or 13, wherein the indication of listen-before-talk process adopted on interruption of the PUSCH transmission comprises an explicit signal for the indication.
15. The method of claim 14, wherein the explicit signal for the indication comprises any of a value of an additional bit in downlink control information (DCI) sent by the base station to the UE, an additional parameter in radio resource control (RRC) signalling.
16. The method of any of claims 12 or 13, wherein the indication of listen-before-talk process adopted on interruption of the PUSCH transmission comprises an implicit signal for the indication.
17. The method of claim 16, wherein the implicit signal for the indication comprises a high value of a priority index for the PUSCH transmission.
18. The method of any of claims 12 to 17, used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of DL symbols during transmission of the repetitions and the indication of listen-before-talk process adopted on interruption of the PUSCH transmission is caused by the presence of DL symbols comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the base station to the UE, an additional parameter in RRC signalling.
19. The method of any of claims 12 to 18, used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by the presence of invalid symbols during transmission of the repetitions and the indication of listen-before-talk process adopted on interruption of the PUSCH transmission caused by the presence of invalid symbols comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the base station to the UE, an additional parameter in RRC signalling.
20. The method of any of claims 12 to 19, used when the interruption of transmission of the repetitions in the PUSCH transmission is caused by a slot boundary producing a one-symbol repetition and the indication of listen-before-talk process adopted on interruption of the PUSCH transmission caused by a slot boundary producing a one-symbol repetition comprises an explicit signal comprising any of a value of an additional bit in DCI sent by the base station to the UE, an additional parameter in RRC signalling.

21. The method of claim 14, wherein the explicit signal comprises a value of a first additional bit in DCI for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a value of a second additional bit in DCI for interruption caused by a slot boundary producing a one-symbol repetition.
22. The method of claim 14, wherein the explicit signal comprises a first additional parameter in RRC signalling for interruption caused by any of the presence of DL symbols, the presence of invalid symbols and a second additional parameter in RRC signalling for interruption caused by a slot boundary producing a one-symbol repetition.
23. A UE comprising a processor arranged to perform the method of any one of claims 12 to 22.
24. A non-transitory computer readable medium storing instructions, which when executed by a computer, perform the method of any one of claims 12 to 22.
25. A method of enhancing performance of a physical uplink shared channel, PUSCH, repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method comprising:
- scheduling, by the base station, resources and number of repetitions in the PUSCH transmission;
 - establishing, by the base station, an indication of listen before talk (listen-before-talk) process adopted on interruption of the PUSCH transmission;
 - receiving, by the UE, the scheduled resources and number of repetitions in the PUSCH transmission;
 - receiving, by the UE, the indication of listen-before-talk process adopted on interruption of the PUSCH transmission;
 - executing, by the UE, a listen-before-talk procedure to acquire the PUSCH;
 - proceeding, by the UE, with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;
 - when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of listen-before-talk process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method without execution of an additional listen-before-talk procedure.

26. There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method carried out by the UE and the method comprising:
- receiving scheduled resources and number of repetitions in the PUSCH transmission;
 - receiving an indication of transmission process adopted on occurrence of a one-symbol repetition;
 - executing a listen-before-talk procedure to acquire the PUSCH;
 - proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;
 - on occurrence of a one-symbol repetition, the indication of transmission process adopted on occurrence of a one-symbol repetition causing the UE to proceed with transmission of the one-symbol repetition and further repetitions in the PUSCH transmission using the PUSCH repetition Type B method.
27. The method of claim 26, wherein the PUSCH transmission is a PUSCH transmission of ultra-reliable, low-latency communications (URLLC) having high priority.
28. The method of any of claims 26 or 27, wherein the one-symbol repetition contains DMRS.
29. The method of any of claims 26 to 28, wherein the indication of transmission process adopted on occurrence of a one-symbol repetition comprises an explicit signal for the indication.
30. The method of claim 29, wherein the explicit signal for the indication comprises any of a value of an additional bit in DCI sent by the base station to the UE, an additional parameter in RRC signalling.
31. The method of any of claims 26 to 28, wherein the indication of transmission process adopted on occurrence of a one-symbol repetition comprises an implicit signal for the indication comprising a high value of a priority index for the PUSCH transmission.
32. A UE comprising a processor arranged to perform the method of any one of claims 26 to 31.
33. A non-transitory computer readable medium storing instructions, which when executed by a computer, perform the method of any one of claims 26 to 31.

34. There is provided a method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method comprising:

scheduling, by the base station, resources and number of repetitions in the PUSCH transmission;

establishing, by the base station, an indication of transmission process adopted on occurrence of a one-symbol repetition;

receiving, by the UE, the scheduled resources and number of repetitions in the PUSCH transmission;

receiving, by the UE, the indication of transmission process adopted on occurrence of a one-symbol repetition;

executing, by the UE, a listen-before-talk procedure to acquire the PUSCH;

proceeding, by the UE, with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

on occurrence of a one-symbol repetition, the indication of transmission process adopted on occurrence of a one-symbol repetition causing the UE to proceed with transmission of the one-symbol repetition and further repetitions in the PUSCH transmission using the PUSCH repetition Type B method.

35. A method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method carried out by the UE and the method comprising:

receiving scheduled resources, number of repetitions and DL symbols in the PUSCH transmission;

receiving an indication of transmission process adopted on interruption of the PUSCH transmission;

executing, a listen-before-talk procedure to acquire the PUSCH in unlicensed spectrum;

proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to switch at least some of the DL symbols to UL symbols and proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of the UL symbols.

36. The method of claim 35, wherein the indication of transmission process adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the base station has no DL data to transmit by means of the DL symbols.

37. The method of claim 35, wherein the indication of transmission process adopted on interruption of the PUSCH transmission causes the UE to switch all of the DL symbols to UL symbols when the base station has DL data to transmit by means of the DL symbols and UL data of the repetitions has higher priority than the DL data.

38. The method of any of claims 35 to 37, wherein, for DG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises any of a dynamic SFI signal sent to the UE, a value of an additional bit of a DCI for UL resource grant, a high value of a priority index for the PUSCH transmission.

39. The method of any of claims 35 to 38, wherein, for CG transmission, the indication of transmission process adopted on interruption of the PUSCH transmission comprises any of a high value of a priority index for the PUSCH transmission, a DCI format 2_0.

40. A UE comprising a processor arranged to perform the method of any one of claims 35 to 39.

41. A non-transitory computer readable medium storing instructions, which when executed by a computer, perform the method of any one of claims 35 to 39.

42. A method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method comprising:

scheduling, by the base station, resources number of repetitions and DL symbols in the PUSCH transmission;

establishing, by the base station, an indication of transmission process adopted on interruption of the PUSCH transmission;

receiving, by the UE, the scheduled resources, number of repetitions and DL symbols in the PUSCH transmission;

receiving, by the UE, the indication of transmission process adopted on interruption of the PUSCH transmission;

executing, by the UE, a listen-before-talk procedure to acquire the PUSCH in unlicensed spectrum;

proceeding, by the UE, with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH

transmission causing the UE to switch at least some of the DL symbols to UL symbols and proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of the UL symbols.

43. A method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method carried out by the UE and the method comprising:

- receiving scheduled resources and number of repetitions in the PUSCH transmission;
- receiving an indication of transmission process adopted on interruption of the PUSCH transmission;
- executing a listen-before-talk procedure to acquire the PUSCH in unlicensed spectrum;
- proceeding with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of semi-static flexible symbols in the scheduled resource.

44. A UE comprising a processor arranged to perform the method of claim 43.

45. A non-transitory computer readable medium storing instructions, which when executed by a computer, perform the method of claim 43.

46. A method of enhancing performance of a PUSCH repetition Type B method used for repetitions in a PUSCH transmission by a UE to a base station of a wireless communications network, the method comprising:

- scheduling, by the base station, resources and number of repetitions in the PUSCH transmission;
- establishing, by the base station, an indication of transmission process adopted on interruption of the PUSCH transmission;
- receiving, by the UE, the scheduled resources and number of repetitions in the PUSCH transmission;
- receiving, by the UE, the indication of transmission process adopted on interruption of the PUSCH transmission;
- executing, by the UE, a listen-before-talk procedure to acquire the PUSCH in unlicensed spectrum;

proceeding, by the UE, with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method;

when an interruption of transmission of the repetitions in the PUSCH transmission is encountered, the indication of transmission process adopted on interruption of the PUSCH transmission causing the UE to proceed with transmission of the repetitions in the PUSCH transmission using the PUSCH repetition Type B method by means of semi-static flexible symbols in the scheduled resource.

Channel Access Priority Class (ρ)	m_ρ	$CW_{min,\rho}$	$CW_{max,\rho}$	$T_{mcot,\rho}$	allowed CW_ρ sizes
1	1	3	7	2 ms	{3,7}
2	1	7	15	3 ms	{7,15}
3	3	15	63	8 or 10 ms	{15,31,63}
4	7	15	1023	8 or 10 ms	{15,31,63,127,255,511,1023}

Fig. 1

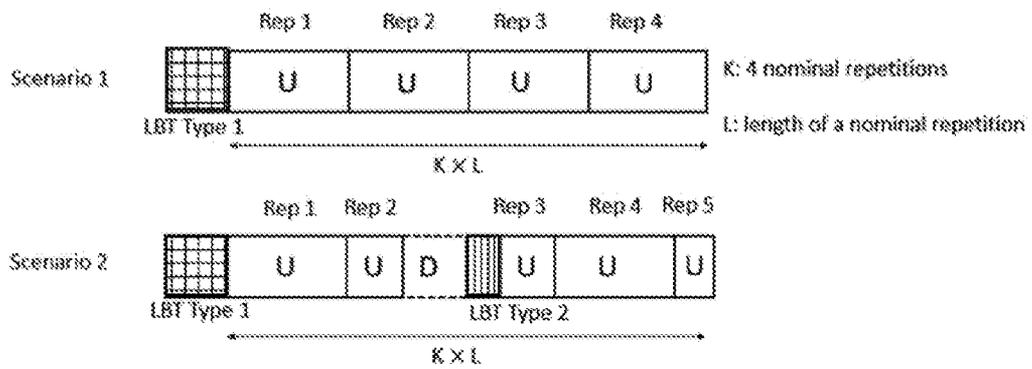


Fig. 2

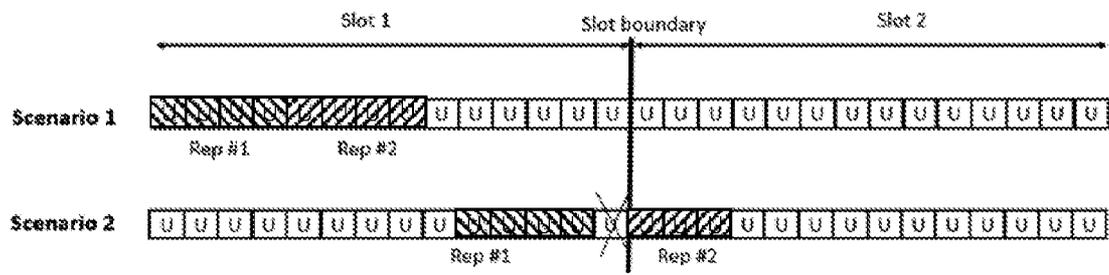


Fig. 3

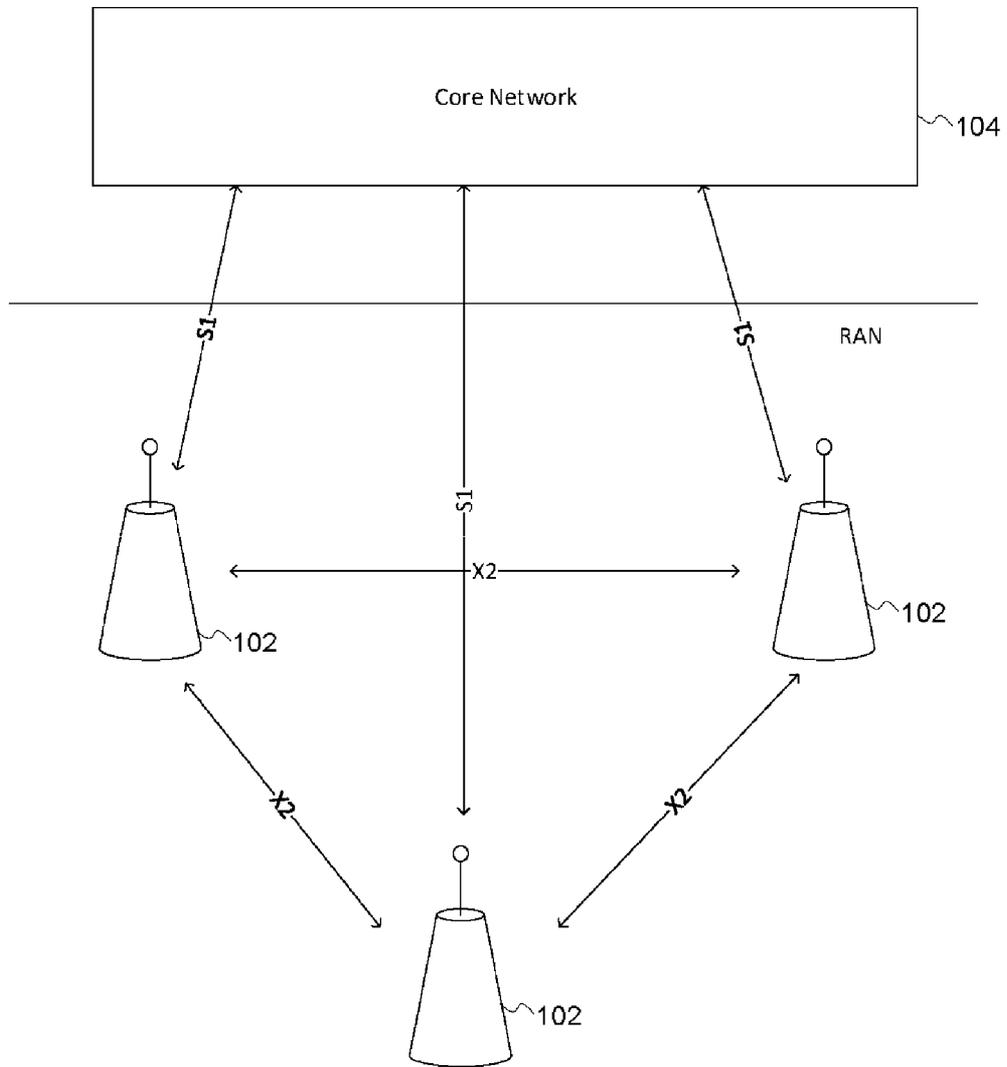


Fig. 4

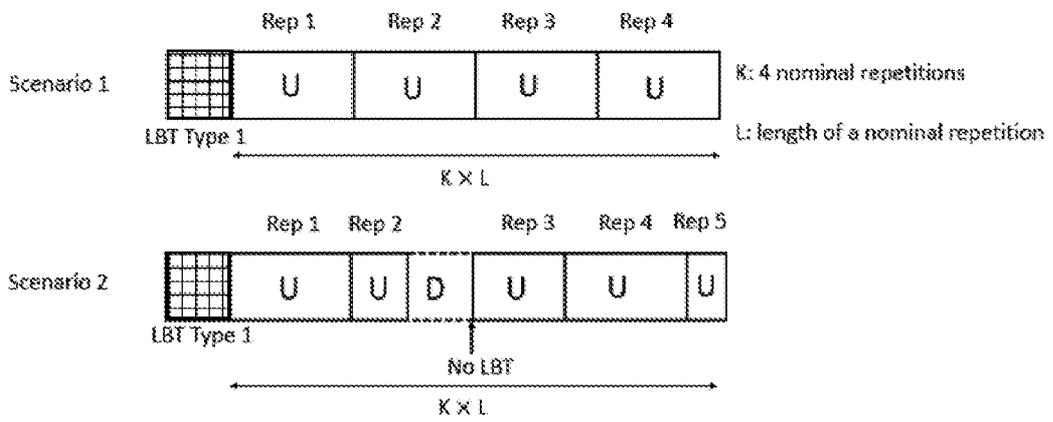


Fig. 5

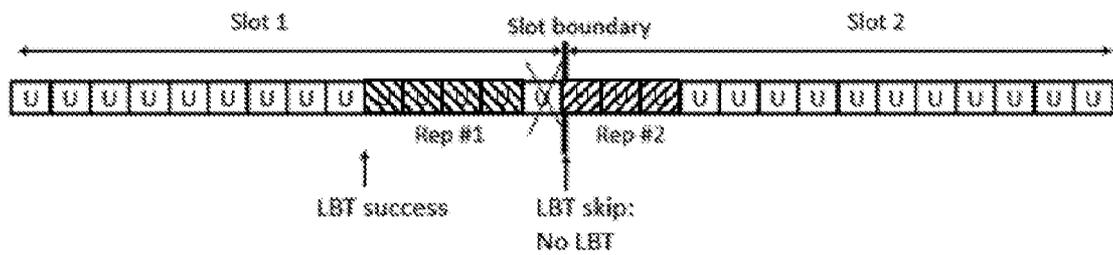


Fig. 6

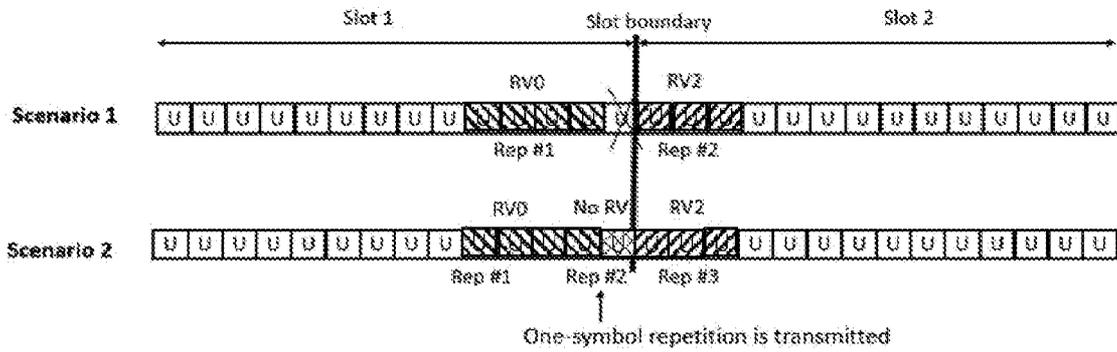


Fig. 7

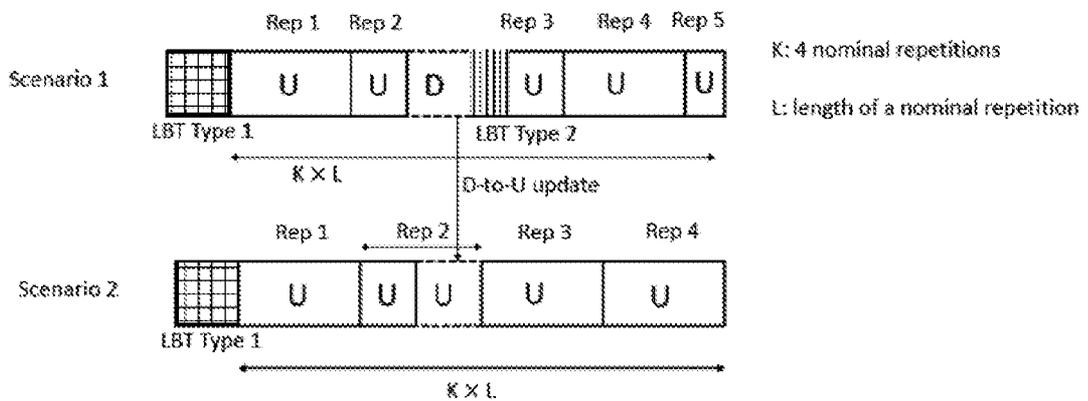


Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/111243

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		
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)		
CNPAT,WPI,EPODOC,CNKI,3GPP: enhanc+, PUSCH, repetition+, type, B, one, single, symbol, process, procedure, indicat+, LBT, listen before talk, no, skip+, additional, slot, boundary, interrupt+, SFI, DL, UL		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	TCL. "Enhancements for unlicensed band URLLC/IIoT" 3GPP TSG RAN WG1 #102-e R1-2005768, 07 August 2020 (2020-08-07), sections 3-4	12-25, 35-46
A	CN 111225444 A (BEIJING SPREADTRUM HI-TECH COMMUNICATIONS TECHNOLOGY CO., LTD.) 02 June 2020 (2020-06-02) description, paragraphs [0072]-[0097]	1-46
A	CN 111246582 A (ZHANXUN SEMICONDUCTOR NANJING CO., LTD.) 05 June 2020 (2020-06-05) the whole document	1-46
A	WO 2020033785 A1 (INTEL CORPORATION) 13 February 2020 (2020-02-13) the whole document	1-46
A	WO 2020033884 A1 (INTEL CORPORATION) 13 February 2020 (2020-02-13) the whole document	1-46
A	WO 2020146854 A1 (APPLE INC.) 16 July 2020 (2020-07-16) the whole document	1-46
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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
25 October 2021		05 November 2021
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		LIU,Rui
Facsimile No. (86-10)62019451		Telephone No. 86-10-53961591

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2021/111243

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	111225444	A	02 June 2020	None			
CN	111246582	A	05 June 2020	None			
WO	2020033785	A1	13 February 2020	CN	112544051	A	23 March 2021
WO	2020033884	A1	13 February 2020	CN	112567662	A	26 March 2021
WO	2020146854	A1	16 July 2020	None			