

DESCRIPTION

**Title Of Invention: COMMUNICATION APPARATUS AND METHOD FOR MSG5
PHYSICAL UPLINK SHARED CHANNEL (PUSCH) ENHANCEMENT**

TECHNICAL FIELD

[1] The following disclosure relates to a communication apparatus and a communication method, and more particularly, for physical uplink (UL) shared channel (PUSCH) enhancement.

BACKGROUND

[2] Coverage is one of the key factors for network deployments of an operator due to its directly impacts on service quality, capital expenditure and operating expenditure. In Releases (Rel.) 15 and 16, PUSCH repetition type A and PUSCH repetition type B are supported based on consecutive physical slots, where UE reports capability of repetition of PUSCH via dedicated higher-layer signaling in radio resource control (RRC). Both PUSCH repetition type A and type B can improve coverage performance, but they were designed to target to different purposes, i.e., PUSCH repetition type A is to achieve higher time diversity gain and PUSCH repetition type B is to perform low latency operation for Ultra Reliable and Low Latency Communications (URLLC) service. Please be noted that Rel. 15/16 PUSCH repetition type A and type B are only applicable after a report of UE capability via dedicated Radio Resource Control (RRC) signalling. PUSCH repetition type B is to perform low latency operation for Ultra Reliable and Low Latency Communications (URLLC) service.

[3] UL channels were identified as bottleneck channels in 5G new radio (NR). Rel. 17 and Rel. 18 specified to enhance coverages of message 4 (Msg4) Physical Uplink Control Channel (PUCCH) for hybrid automatic repeat request acknowledgment (HARQ-ACK) of Msg4 Physical Downlink Shared Channel (PDSCH), message 3 (Msg3) PUSCH carrying RRC Setup Request message (also known as (aka) *RRCSetupRequest* in standards) and Physical Random Access Channel (PRACH) (Msg1). Msg5 PUSCH carrying *RRCSetupComplete* (it occurs after Msg4 PUCCH for HARQ-ACK of Msg4 PDSCH) has not yet been enhanced so far, hence it might cause that gNodeB (gNB) is unable to receive RRC Setup Complete message (i.e., *RRCSetupComplete* in 3GPP standards) from a user equipment (UE) with poor channel condition and the UE is unable to access to network successfully. This happens before any report of UE capability via dedicated Radio Resource Control (RRC) signalling.

[4] There is thus a need for a communication apparatus and a communication method for Msg5 PUSCH enhancement such as enhancing coverage performance of Msg5 PUSCH carrying *RRCSetupComplete* message to solve the above-mentioned issues. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

SUMMARY

[5] Non-limiting and exemplary embodiments facilitate providing communication apparatuses and communication methods for enhancing coverage performance of Msg5 PUSCH carrying a RRC Setup Complete message.

[6] In a first aspect, the present disclosure provides a first communication apparatus comprising: circuitry, which in operation, determines a plurality of resources for one or more PUSCH (Physical Uplink Shared Channel) transmissions, the one or more PUSCH transmissions indicating that a Radio Resource Control (RRC) setup with a second communication apparatus is completed; and a transmitter, which in operation, performs the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

[7] In a second aspect, the present disclosure provides a second communication apparatus comprising: circuitry, which in operation, schedules to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed; and a receiver, which in operation, receives the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

[8] In a third aspect, the present disclosure provides a communication method implemented by a first communication apparatus, comprising: determining a plurality of resources for one or more PUSCH transmissions, the one or more PUSCH transmissions indicating that a RRC setup with a second communication apparatus is completed; and performing the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

[9] In a fourth aspect, the present disclosure provides a communication method implemented by a second communication apparatus, comprising: scheduling to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH

transmissions indicating that a RRC setup with the second communication apparatus is completed; and receiving the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

[10] Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[11] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views and which together with the detailed description below are incorporated in and form part of the specification, serve to illustrate various embodiments and to explain various principles and advantages in accordance with present embodiments.

[12] Figure 1 shows an exemplary 3GPP next generation radio access network (NG-RAN) architecture to which exemplary embodiments of the present disclosure may be applied.

[13] Figure 2 depicts a schematic drawing which shows functional split between NG-RAN and 5GC to which exemplary embodiments of the present disclosure may be applied.

[14] Figure 3 depicts a sequence diagram for radio resource control (RRC) connection setup/reconfiguration procedures to which exemplary embodiments of the present disclosure may be applied.

[15] Figure 4 depicts a schematic drawing showing usage scenarios of Enhanced mobile broadband (eMBB), Massive Machine Type Communications (mMTC) and Ultra Reliable and Low Latency Communications (URLLC) to which exemplary embodiments of the present disclosure may be applied.

[16] Figure 5 shows a block diagram showing an exemplary 5G system architecture for Vehicle-to-everything (V2X) communication in a non-roaming scenario.

[17] Figure 6 shows a diagram illustrating a whole process of a RRC setup procedure and a RRC reconfiguration procedure between a UE and a gNB.

[18] Figure 7 shows a schematic diagram illustrating an example configuration of a communication apparatus for Msg5 PUSCH enhancement in accordance with various embodiments of the present disclosure.

[19] Figure 8 shows a flowchart illustrating a method for Msg5 PUSCH enhancement according to various embodiments of the present disclosure.

[20] Figure 9 shows a flowchart illustrating another method for Msg5 PUSCH enhancement according to various embodiments of the present disclosure.

[21] Figure 10A shows an example format of Msg5 PUSCH repetitions over multiple slots according to a first embodiment of the present disclosure.

[22] Figure 10B shows an example format of a processing of a single transport block over multiple slots (TBoMS) for Msg5 PUSCH according to a second embodiment of the present disclosure.

[23] Figure 11 shows an example format of M repetitions of the single TBoMS for Msg5 PUSCH according to a third embodiment of the present disclosure.

[24] Figure 12 shows an example format of applying joint channel estimation over Msg5 PUSCH repetitions according to a fourth embodiment of the present disclosure.

[25] Figure 13 shows an example of using a part of Msg3 PUSCH to send a request of Msg5 PUSCH enhancement according to an embodiment of the present disclosure.

[26] Figure 14 shows an example table of Logical Channel ID (LCID) values indicated by different codepoints/indices of the R field in LCID field for requesting Msg5 PUSCH enhancement.

[27] Figure 15 shows an example *RRCSetupRequest* Information Elements (IEs) carried by a Msg3 for requesting Msg5 PUSCH enhancement according to an embodiment of the present disclosure.

[28] Figure 16 shows a Msg4 PUCCH carrying a HARQ ACK/NACK of a Msg4 PDSCH for requesting Msg5 PUSCH enhancement according to an embodiment of the present disclosure.

[29] Figure 17 shows an example *RRCSetup* message carried by Msg4 PDSCH for Msg5 PUSCH enhancement according to an embodiment of the present disclosure.

[30] Figure 18 shows a flowchart illustrating a communication method implemented by a UE for enabling a Msg5 PUSCH repetition according to various embodiments of the present disclosure.

[31] Figure 19 shows a flowchart illustrating a communication method implemented by a gNB for enabling a Msg5 PUSCH repetition according to various embodiments of the present disclosure.

[32] Figure 20 shows a diagram illustrating an example of a detailed RRC setup procedure between a UE and a gNB for enabling Msg5 PUSCH repetition according to an embodiment of the present disclosure.

[33] Skilled artisans will appreciate that elements in the figures are illustrated for simplicity and clarity and have not necessarily been depicted to scale. For example, the dimensions of some of the elements in the illustrations, block diagrams or flowcharts may be exaggerated in respect to other elements to help an accurate understanding of the present embodiments.

DETAILED DESCRIPTION

[34] Some embodiments of the present disclosure will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[35] 3GPP has been working at the next release for the 5th generation cellular technology, simply called 5G, including the development of a new radio access technology (NR) operating in frequencies ranging up to 100 GHz. The first version of the 5G standard was completed at the end of 2017, which allows proceeding to 5G NR standard-compliant trials and commercial deployments of smartphones.

[36] The second version of the 5G standard was completed in June 2020, which further expand the reach of 5G to new services, spectrum and deployment such as unlicensed spectrum (NR-U), non-public network (NPN), time sensitive networking (TSN) and cellular-V2X.

[37] Among other things, the overall system architecture assumes an NG-RAN (Next Generation – Radio Access Network) that comprises gNBs, providing the NG-radio access user plane (SDAP/PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The gNBs are interconnected with each other by means of the Xn interface. The gNBs are also connected by means of the Next Generation (NG) interface to the NGC (Next Generation Core), more specifically to the AMF (Access and Mobility Management Function) (e.g., a particular core entity performing the AMF) by means of the NG-C interface and to the UPF (User Plane Function) (e.g., a particular core entity performing the UPF) by means of the

NG-U interface. The NG-RAN architecture is illustrated in Figure 1 (see e.g., 3GPP TS 38.300 v16.3.0).

[38] The user plane protocol stack for NR (see e.g., 3GPP TS 38.300, section 4.4.1) comprises the PDCP (Packet Data Convergence Protocol, see section 6.4 of TS 38.300), RLC (Radio Link Control, see section 6.3 of TS 38.300) and MAC (Medium Access Control, see section 6.2 of TS 38.300) sublayers, which are terminated in the gNB on the network side. Additionally, a new access stratum (AS) sublayer (SDAP, Service Data Adaptation Protocol) is introduced above PDCP (see e.g., sub-clause 6.5 of 3GPP TS 38.300). A control plane protocol stack is also defined for NR (see for instance TS 38.300, section 4.4.2). An overview of the Layer 2 functions is given in sub-clause 6 of TS 38.300. The functions of the PDCP, RLC and MAC sublayers are listed respectively in sections 6.4, 6.3, and 6.2 of TS 38.300. The functions of the RRC layer are listed in sub-clause 7 of TS 38.300.

[39] For instance, the Medium-Access-Control layer handles logical-channel multiplexing, and scheduling and scheduling-related functions, including handling of different numerologies.

[40] The physical layer (PHY) is for example responsible for coding, PHY hybrid automatic repeat request (HARQ) processing, modulation, multi-antenna processing, and mapping of the signal to the appropriate physical time-frequency resources. It also handles mapping of transport channels to physical channels. The physical layer provides services to the MAC layer in the form of transport channels. A physical channel corresponds to the set of time-frequency resources used for transmission of a particular transport channel, and each transport channel is mapped to a corresponding physical channel. For instance, the physical channels are PRACH (Physical Random Access Channel), PUSCH (Physical Uplink Shared Channel) and

PUCCH (Physical Uplink Control Channel) for uplink, PDSCH (Physical Downlink Shared Channel), PDCCH (Physical Downlink Control Channel) and PBCH (Physical Broadcast Channel) for downlink, and PSSCH (Physical Sidelink Shared Channel), PSCCH (Physical Sidelink Control Channel) and Physical Sidelink Feedback Channel (PSFCH) for sidelink (SL).

[41] SL supports UE-to-UE direct communication using the SL resource allocation modes, physical layer signals/channels, and physical layer procedures. Two new radio (NR) SL resource allocation modes are supported: (a) mode 1, where the NR SL resource allocation is provided by the network; and (b) mode 2, where UE decides NR SL transmission resource in the resource pool(s). Two SL resource allocations modes are applicable to LTE V2X: (a) mode 3, where the LTE SL resource allocation is scheduled by eNB primarily for transmission of periodically occurring messages; and (b) mode 4, where the UE decides autonomously the LTE SL transmission resource in the resource pool(s).

[42] PSCCH indicates resource and other transmission parameters used by a UE for PSSCH. PSCCH transmission is associated with a demodulation reference signal (DMRS). PSSCH transmits the transport blocks (TBs) of data themselves, and control information for HARQ procedure and channel state information (CSI) feedback triggers, etc. At least 6 Orthogonal Frequency Division Multiplexing (OFDM) symbols within a slot are used for PSSCH transmission. PSSCH transmission is associated with a DMRS and may be associated with a phase-tracking reference signal (PT-RS).

[43] PSFCH carries HARQ feedback over the SL from a UE which is an intended recipient of a PSSCH transmission to the UE which performed the transmission. PSFCH sequence is

transmitted in one PRB repeated over two OFDM symbols near the end of the SL resource in a slot.

[44] The SL synchronization signal consists of SL primary and SL secondary synchronization signals (S-PSS, S-SSS), each occupying 2 symbols and 127 subcarriers. Physical Sidelink Broadcast Channel (PSBCH) occupies 9 and 5 symbols for normal and extended cyclic prefix cases respectively, including the associated demodulation reference signal (DM-RS).

[45] Regarding physical layer procedure for HARQ feedback for sidelink, SL HARQ feedback uses PSFCH and can be operated in one of two options. In one option, which can be configured for unicast and groupcast, PSFCH transmits either ACK or NACK using a resource dedicated to a single PSFCH transmitting UE. In another option, which can be configured for groupcast, PSFCH transmits NACK, or no PSFCH signal is transmitted, on a resource that can be shared by multiple PSFCH transmitting UEs.

[46] In SL resource allocation mode 1, a UE which received PSFCH can report SL HARQ feedback to gNB via PUCCH or PUSCH.

[47] Regarding physical layer procedure for power control for sidelink, for in-coverage operation, the power spectral density of the SL transmissions can be adjusted based on the pathloss from the gNB, whereas for unicast, the power spectral density of some SL transmissions can be adjusted based on the pathloss between the two communicating UEs.

[48] Regarding physical layer procedure for CSI report, for unicast, channel state information reference signal (CSI-RS) is supported for CSI measurement and reporting in sidelink. A CSI report is carried in a SL MAC CE.

[49] For measurement on the sidelink, the following UE measurement quantities are supported:

- PSBCH reference signal received power (PSBCH RSRP);
- PSSCH reference signal received power (PSSCH-RSRP);
- PSCCH reference signal received power (PSCCH-RSRP);
- Sidelink received signal strength indicator (SL RSSI);
- Sidelink channel occupancy ratio (SL CR);
- Sidelink channel busy ratio (SL CBR).

[50] Use cases / deployment scenarios for NR could include enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC), massive machine type communication (mMTC), which have diverse requirements in terms of data rates, latency, and coverage. For example, eMBB is expected to support peak data rates (20Gbps for downlink and 10Gbps for uplink) and user-experienced data rates in the order of three times what is offered by IMT-Advanced. On the other hand, in case of URLLC, the tighter requirements are put on ultra-low latency (0.5ms for UL and DL each for user plane latency) and high reliability ($1-10^{-5}$ within 1ms). Finally, mMTC may preferably require high connection density (1,000,000 devices/km² in an urban environment), large coverage in harsh environments, and extremely long-life battery for low cost devices (15 years).

[51] Therefore, the OFDM numerology (e.g., subcarrier spacing, OFDM symbol duration, cyclic prefix (CP) duration, number of symbols per scheduling interval) that is suitable for one use case might not work well for another. For example, low-latency services may preferably require a shorter symbol duration (and thus larger subcarrier spacing) and/or fewer symbols per scheduling interval (also known as transmission time interval (TTI)) than an mMTC service. Furthermore, deployment scenarios with large channel delay spreads may preferably require a longer CP duration than scenarios with short delay spreads. The subcarrier spacing should be optimized accordingly to retain the similar CP overhead. NR may support more than one value of subcarrier spacing. Correspondingly, subcarrier spacing of 15kHz, 30kHz, 60 kHz... are being considered at the moment. The symbol duration T_u and the subcarrier spacing Δf are directly related through the formula $\Delta f = 1 / T_u$. In a similar manner as in LTE systems, the term “resource element” can be used to denote a minimum resource unit being composed of one subcarrier for the length of one OFDM/SC-FDMA symbol.

[52] In the new radio system 5G-NR for each numerology and carrier a resource grid of subcarriers and OFDM symbols is defined respectively for uplink and downlink. Each element in the resource grid is called a resource element and is identified based on the frequency index in the frequency domain and the symbol position in the time domain (see 3GPP TS 38.211 v16.3.0).

[53] Figure 2 illustrates functional split between NG-RAN and 5GC to which exemplary embodiments of the present disclosure may be applied. NG-RAN logical node is a gNB or ng-eNB. The 5GC has logical nodes AMF, UPF and SMF.

[54] In particular, the gNB and/or ng-eNB host the following main functions:

- Functions for Radio Resource Management such as Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
- IP header compression, encryption and integrity protection of data;
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE;
- Routing of User Plane data towards UPF(s);
- Routing of Control Plane information towards AMF;
- Connection setup and release;
- Scheduling and transmission of paging messages;
- Scheduling and transmission of system broadcast information (originated from the AMF or OAM);
- Measurement and measurement reporting configuration for mobility and scheduling;
- Transport level packet marking in the uplink;
- Session Management;
- Support of Network Slicing;
- QoS Flow management and mapping to data radio bearers;
- Support of UEs in RRC_INACTIVE state;
- Distribution function for NAS messages;
- Radio access network sharing;
- Dual Connectivity;
- Tight interworking between NR and E-UTRA.

[55] The Access and Mobility Management Function (AMF) hosts the following main functions:

- Non-Access Stratum, NAS, signaling termination;
- NAS signaling security;
- Access Stratum, AS, Security control;
- Inter Core Network, CN, node signaling for mobility between 3GPP access networks;
- Idle mode UE Reachability (including control and execution of paging retransmission);
- Registration Area management;
- Support of intra-system and inter-system mobility;
- Access Authentication;
- Access Authorization including check of roaming rights;
- Mobility management control (subscription and policies);
- Support of Network Slicing;
- Session Management Function, SMF, selection.

[56] Furthermore, the User Plane Function, UPF, hosts the following main functions:

- Anchor point for Intra-/Inter-RAT mobility (when applicable);
- External PDU session point of interconnect to Data Network;
- Packet routing & forwarding;
- Packet inspection and User plane part of Policy rule enforcement;
- Traffic usage reporting;
- Uplink classifier to support routing traffic flows to a data network;
- Branching point to support multi-homed PDU session;
- QoS handling for user plane, e.g., packet filtering, gating, UL/DL rate enforcement;
- Uplink Traffic verification (SDF to QoS flow mapping);
- Downlink packet buffering and downlink data notification triggering.

[57] Finally, the Session Management function, SMF, hosts the following main functions:

- Session Management;
- UE IP address allocation and management;
- Selection and control of UP function;
- Configures traffic steering at User Plane Function, UPF, to route traffic to proper destination;
- Control part of policy enforcement and QoS;
- Downlink Data Notification.

[58] Figure 3 illustrates some interactions between a UE, gNB, and AMF (an 5GC entity) in the context of a transition of the UE from RRC_IDLE to RRC_CONNECTED for the NAS part (see TS 38.300 v16.3.0). The transition steps are as follows:

1. The UE requests to setup a new connection from RRC_IDLE.

2/2a. The gNB completes the RRC setup procedure.

NOTE: The scenario where the gNB rejects the request is described below.

3. The first NAS message from the UE, piggybacked in *RRCSetupComplete*, is sent to AMF.

4/4a/5/5a. Additional NAS messages may be exchanged between UE and AMF, see TS 23.502 .

6. The AMF prepares the UE context data (including PDU session context, the Security Key, UE Radio Capability and UE Security Capabilities, etc.) and sends it to the gNB.

7/7a. The gNB activates the AS security with the UE.

8/8a. The gNB performs the reconfiguration to setup SRB2 and DRBs.

9. The gNB informs the AMF that the setup procedure is completed.

[59] RRC is a higher layer signaling (protocol) used for UE and gNB configuration. In particular, this transition involves that the AMF prepares the UE context data (including e.g., PDU session context, the Security Key, UE Radio Capability and UE Security Capabilities, etc.) and sends it to the gNB with the INITIAL CONTEXT SETUP REQUEST. Then, the gNB activates the AS security with the UE, which is performed by the gNB transmitting to the UE a *SecurityModeCommand* message and by the UE responding to the gNB with the *SecurityModeComplete* message. Afterwards, the gNB performs the reconfiguration to setup the Signaling Radio Bearer 2, SRB2, and Data Radio Bearer(s), DRB(s) by means of transmitting to the UE the *RRCReconfiguration* message and, in response, receiving by the gNB the *RRCReconfigurationComplete* from the UE. For a signaling-only connection, the steps relating to the *RRCReconfiguration* are skipped since SRB2 and DRBs are not setup. Finally, the gNB informs the AMF that the setup procedure is completed with the INITIAL CONTEXT SETUP RESPONSE.

[60] Figure 4 illustrates some of the use cases for 5G NR. In 3rd generation partnership project new radio (3GPP NR), three use cases are being considered that have been envisaged to support a wide variety of services and applications by IMT-2020. The specification for the phase 1 of enhanced mobile-broadband (eMBB) has been concluded. In addition to further extending the eMBB support, the current and future work would involve the standardization for ultra-reliable and low-latency communications (URLLC) and massive machine-type communications. Figure 4 illustrates some examples of envisioned usage scenarios for IMT for 2020 and beyond (see e.g., ITU-R M.2083 Figure 2).

[61] The URLLC use case has stringent requirements for capabilities such as throughput, latency and availability and has been envisioned as one of the enablers for future vertical

applications such as wireless control of industrial manufacturing or production processes, remote medical surgery, distribution automation in a smart grid, transportation safety, etc. Ultra-reliability for URLLC is to be supported by identifying the techniques to meet the requirements set by TR 38.913. For NR URLLC in Release 15, key requirements include a target user plane latency of 0.5 ms for UL (uplink) and 0.5 ms for DL (downlink). The general URLLC requirement for one transmission of a packet is a BLER (block error rate) of $1E-5$ for a packet size of 32 bytes with a user plane latency of 1ms.

[62] From the physical layer perspective, reliability can be improved in a number of possible ways. The current scope for improving the reliability involves defining separate CQI tables for URLLC, more compact Downlink Control Information (DCI) formats, repetition of PDCCH, etc. However, the scope may widen for achieving ultra-reliability as the NR becomes more stable and developed (for NR URLLC key requirements). Particular use cases of NR URLLC in Rel. 15 include Augmented Reality/Virtual Reality (AR/VR), e-health, e-safety, and mission-critical applications.

[63] Moreover, technology enhancements targeted by NR URLLC aim at latency improvement and reliability improvement. Technology enhancements for latency improvement include configurable numerology, non-slot-based scheduling with flexible mapping, grant free (configured grant) uplink, slot-level repetition for data channels, and downlink pre-emption. Pre-emption means that a transmission for which resources have already been allocated is stopped, and the already allocated resources are used for another transmission that has been requested later, but has lower latency / higher priority requirements. Accordingly, the already granted transmission is pre-empted by a later transmission. Pre-emption is applicable independent of the particular service type. For example, a transmission for a service-type A

(URLLC) may be pre-empted by a transmission for a service type B (such as eMBB). Technology enhancements with respect to reliability improvement include dedicated CQI/MCS tables for the target BLER of $1E-5$.

[64] The use case of mMTC (massive machine type communication) is characterized by a very large number of connected devices typically transmitting a relatively low volume of non-delay sensitive data. Devices are required to be low cost and to have a very long battery life. From NR perspective, utilizing very narrow bandwidth parts is one possible solution to have power saving from UE perspective and enable long battery life.

[65] As mentioned above, it is expected that the scope of reliability in NR becomes wider. One key requirement to all the cases, and especially necessary for URLLC and mMTC, is high reliability or ultra-reliability. Several mechanisms can be considered to improve the reliability from radio perspective and network perspective. In general, there are a few key potential areas that can help improve the reliability. Among these areas are compact control channel information, data/control channel repetition, and diversity with respect to frequency, time and/or the spatial domain. These areas are applicable to reliability in general, regardless of particular communication scenarios.

[66] For NR URLLC, further use cases with tighter requirements have been identified such as factory automation, transport industry and electrical power distribution, including factory automation, transport industry, and electrical power distribution. The tighter requirements are higher reliability (up to 10^{-6} level), higher availability, packet sizes of up to 256 bytes, time synchronization down to the order of a few μs where the value can be one or a few μs depending

on frequency range and short latency in the order of 0.5 to 1 ms in particular a target user plane latency of 0.5 ms, depending on the use cases.

[67] Moreover, for NR URLLC, several technology enhancements from the physical layer perspective have been identified. Among these are PDCCH (Physical Downlink Control Channel) enhancements related to compact DCI, PDCCH repetition, increased PDCCH monitoring. Moreover, UCI (Uplink Control Information) enhancements are related to enhanced HARQ (Hybrid Automatic Repeat Request) and CSI feedback enhancements. Also, PUSCH enhancements related to mini-slot level hopping and retransmission/repetition enhancements have been identified. The term “mini-slot” refers to a Transmission Time Interval (TTI) including a smaller number of symbols than a slot (a slot comprising fourteen symbols).

[68] The 5G QoS (Quality of Service) model is based on QoS flows and supports both QoS flows that require guaranteed flow bit rate (GBR QoS flows) and QoS flows that do not require guaranteed flow bit rate (non-GBR QoS Flows). At NAS level, the QoS flow is thus the finest granularity of QoS differentiation in a PDU session. A QoS flow is identified within a PDU session by a QoS flow ID (QFI) carried in an encapsulation header over NG-U interface.

[69] For each UE, 5GC establishes one or more PDU Sessions. For each UE, the NG-RAN establishes at least one Data Radio Bearers (DRB) together with the PDU Session, and additional DRB(s) for QoS flow(s) of that PDU session can be subsequently configured (it is up to NG-RAN when to do so), e.g., as shown above with reference to Figure 3. The NG-RAN maps packets belonging to different PDU sessions to different DRBs. NAS level packet filters

in the UE and in the 5GC associate UL and DL packets with QoS Flows, whereas AS-level mapping rules in the UE and in the NG-RAN associate UL and DL QoS Flows with DRBs.

[70] Figure 5 illustrates a 5G NR non-roaming reference architecture (see TS 23.287 v16.4.0, section 4.2.1.1). An Application Function (AF), e.g., an external application server hosting 5G services, exemplarily described in Figure 4, interacts with the 3GPP Core Network in order to provide services, for example to support application influence on traffic routing, accessing Network Exposure Function (NEF) or interacting with the Policy framework for policy control (see Policy Control Function, PCF), e.g., QoS control. Based on operator deployment, Application Functions considered to be trusted by the operator can be allowed to interact directly with relevant Network Functions. Application Functions not allowed by the operator to access directly the Network Functions use the external exposure framework via the NEF to interact with relevant Network Functions.

[71] Figure 5 shows further functional units of the 5G architecture for V2X communication, namely, Unified Data Management (UDM), Policy Control Function (PCF), Network Exposure Function (NEF), Application Function (AF), Unified Data Repository (UDR), Access and Mobility Management Function (AMF), Session Management Function (SMF), and User Plane Function (UPF) in the 5GC, as well as with V2X Application Server (V2AS) and Data Network (DN), e.g., operator services, Internet access or 3rd party services. All or a part of the core network functions and the application services may be deployed and running on cloud computing environments.

[72] In the present disclosure, thus, an application server (for example, AF of the 5G architecture), is provided that comprises a transmitter, which, in operation, transmits a request

containing a QoS requirement for at least one of URLLC, eMBB and mMTC services to at least one of functions (for example NEF, AMF, SMF, PCF, UPF, etc) of the 5GC to establish a PDU session including a radio bearer between a gNodeB and a UE in accordance with the QoS requirement and control circuitry, which, in operation, performs the services using the established PDU session.

[73] In various embodiments below, the term “resources” may refer to “time domain resources” which may include multiple symbols or slots; the phrase “a request of a Msg5 PUSCH repetition” may be referred as “a request for a Msg5 PUSCH repetition”, and the phrase “a request of a repetition number” may be referred as “a request for a repetition number”.

[74] Request information may comprise and refer to one or more of a request for a Msg5 PUSCH repetition, a repetition number to request for a Msg5 PUSCH repetition, a request for a processing of a single transport block over multiple slots (TBoMS), a joint request for a repetition of a single TBoMS of Msg5 PUSCH, or a joint request for joint channel estimation (JCE) (i.e., DMRS bundling) over Msg5 PUSCH repetitions in various embodiments below.

[75] Control information may comprise or refer to one or more of a repetition number of Msg5 PUSCH, a number of slots and a number of REs per slot, a number of M repetitions or the one or more nominal time domain windows in various embodiments below.

[76] For the below embodiments, “exchange between gNBs” may be replaced with “transmits to another gNBs” or “sends to another gNBs”. Further, “exchange between gNBs” may be replaced with “transmits to a user equipment (UE)” or “sends to a UE”.

[77] As mentioned above, UL channels were still identified as bottleneck channels in near radio (NR) based on coverage enhancement (CovEnh) in Rel. 17. The following channels were identified as bottleneck channels:

- For frequency 1 or FR1 (Urban/Rural):
 - 1st priority
 - PUSCH for eMBB
 - PUSCH for VoIP
 - 2nd priority
 - PRACH format B4
 - PUSCH of Msg3
 - PUCCH format 1
 - PUCCH format 3 with 11bits and 22bits
 - Broadcast PDCCH
- For frequency 2 or FR2 (Urban):
 - PUSCH eMBB (DDDSU and DDSU)
 - PUSCH VoIP (DDDSU and DDSU)
 - PUCCH F3 11bits and 22bits
 - PRACH B4
 - PUSCH of Msg3

[78] Rel. 17 specified methods for coverage enhancements of PUSCH, Msg3 PUSCH and PUCCH. Msg3 PUSCH is enhanced based on PUSCH repetition type A for both initial transmission and retransmission. PUCCH is enhanced through joint channel estimation for PUCCH repetition or dynamic indication for PUCCH repetition.

[79] Rel. 18 also specified some methods for coverage enhancements of PRACH, PUSCH and PUCCH. In particular, PRACH (also known as Msg1) is enhanced based on multiple PRACH transmissions with the same beam. PUSCH is further enhanced based on dynamic waveform switching. Msg4 PUCCH for sending HARQ-ACK of Msg4 PDSCH is enhanced based on repetition in Rel. 18 NTN.

[80] Figure 6 shows a diagram 600 illustrating a whole process of a RRC setup procedure between a UE and a gNB. Currently, the uplink transmissions in steps 602, 606, 610 are enhanced in Rel. 17/18 whereas the uplink transmission in step 614 is not enhanced. For initial access, the procedure broadly includes the following four steps:

- Step 1: a UE sends a preamble to a gNB (step 602 in Figure 6)
- Step 2: the gNB sends a Msg2 random access response (RAR) to the UE (step 604 in Figure 6)
- Step 3: the UE sends a Msg3 PUSCH carrying a *RRCSetupRequest* message to the gNB to request for a RRC setup (step 606 in Figure 6)
- Step 4: the gNB sends a Msg4 PDSCH carrying a *RRCSetup* message to the UE (contention resolution) to indicate a RRC setup (step 608 in Figure 6).

[81] After Msg4, the UE sends a PUSCH carrying a *RRCSetupComplete* message to indicate that the RRC setup is completed or to confirm a successful completion of an RRC connection. This PUSCH is also known or named as Msg5 PUSCH. The Msg5 PUSCH carries a larger payload size than the Msg3 PUSCH (e.g., > 100 bytes). It is noted that both Msg3 and Msg5 PUSCHs happen before a report of UE capability via dedicated RRC signalling.

[82] In Rel. 17 and 18, it is suggested that to enable Msg3 PUSCH repetition in Rel. 17 (i.e., the existing feature of Msg3 PUSCH repetition), a UE sends an implicit request to a gNB based on a separate PRACH resource (e.g., preamble). For initial transmission, the gNB sends UL grant for Msg3 PUSCH repetition in Msg2 RAR. The UE determines a repetition number based on a modulation and coding scheme (MCS) info field (4 bits) in Msg2 RAR. For example, 2 most significant bits (MSB bits) are used to obtain one repetition number from a set of 4 candidate values configured by system information block 1 (SIB1), and 2 least significant bits (LSB bits) are used to obtain one MCS index from a set of 4 candidate MCS indices configured by SIB1.

[83] For retransmission, the gNB sends a DCI format 0_0 (i.e., DCI 0_0) with cyclic redundancy check (CRC) scrambled with temporary cell radio network temporary identifier (TC-RNTI) to schedule repetition of Msg3 PUSCH. The UE determines repetition number based on MCS info field (5 bits). For example, 2 MSB bits are used for selecting one repetition number from a set of 4 candidate values configured by SIB, and 3 LSB bits are used for selecting one MCS index from a set of 8 candidate MCS indices configured by SIB1. The first 4 indexes of the 8 candidate MCS indexes are used for initial PUSCH transmission scheduled by RAR UL grant.

[84] As mentioned earlier, as PUSCH has been identified as a bottleneck UL channel, Msg5 PUSCH (step 614 in Figure 6) can also be considered a bottleneck UL channel. While Msg1 PRACH, Msg3 PUSCH and Msg4 PUCCH carrying HARQ-ACK of Msg4 PDSCH (702, 706, 710 in Figure 6, respectively) have been enhanced in Rel. 17/18, Msg5 PUSCH has not yet been enhanced so far. Moreover, the applicability of the existing Rel. 17/18 features of PUSCH coverage enhancement (e.g., repetition) to Msg5 PUSCH has not been considered.

This might cause that the gNB cannot receive RRC setup message from the UE in poor channel conditions and the UE cannot access to network successfully.

[85] Msg5 PUSCH repetition may be enabled based on a similar design concept of the existing feature of Msg3 PUSCH repetition. In particular, a UE sends an implicit request for a Msg5 PUSCH repetition to a gNB based on a separate PRACH resource and the gNB sends a DCI to schedule the Msg5 PUSCH repetition, where 2 MSB bits of MCS information field in the DCI are used to obtain one repetition number from a set of 4 candidate values configured by SIB1, and 3 LSB bits of MCS information field in the DCI are used to obtain one MCS index from a set of 8 candidate MCS indices configured by SIB1.

[86] However, since a gNB needs to reserve separate preambles for UEs to send such request for a Msg5 PUSCH repetition in a serving cell, the number of available preambles may be not enough for other purposes (contention-free random access (CFRA), 2-step RACH, 4-step RACH, feature combination (reduced capability (RedCap), small data (SmallData) transmission, network slicing group (SliceGroup), Msg3-Repetition request). This will reduce provision of PRACH preamble for other purposes. Note that the existing feature of Msg3 PUSCH repetition is an optional UE capability.

[87] There is thus a need for a communication apparatus and a communication method for Msg5 PUSCH enhancement such as enhancing coverage performance of Msg5 PUSCH carrying *RRCSetupComplete* message to solve the above-mentioned issues. Furthermore, other desirable features and characteristics will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and this background of the disclosure.

[88] Figure 7 shows a schematic diagram illustrating an example configuration of a communication apparatus 700 for Msg5 PUSCH enhancement in accordance with various embodiments of the present disclosure. The communication apparatus 700 may be implemented as a UE or a base station in accordance with the present disclosure. As shown in Figure 7, the communication apparatus 700 may include circuitry 714, at least one radio transmitter 702, at least one radio receiver 704, and at least one antenna 712 (for the sake of simplicity, only one antenna is depicted in Figure 7 for illustration purposes). The circuitry 714 may include at least one controller 706 for use in software and/or hardware aided execution of tasks that the at least one controller 706 is designed to perform, including control of communications with one or more other communication apparatuses in a multiple input and multiple output (MIMO) wireless network. The circuitry 714 may furthermore include at least one transmission signal generator 708 and at least one receive signal processor 710. The at least one controller 706 may control the at least one transmission signal generator 708 for generating a downlink signal or a sidelink signal to be sent through the at least one radio transmitter 702 and the at least one receive signal processors 710 for processing an uplink signal, a downlink signal or a sidelink signal received through the at least one radio receiver 704 from the one or more other communication apparatuses. The at least one transmission signal generator 708 and the at least one receive signal processor 710 may be stand-alone modules of the communication apparatus 700 that communicate with the at least one controller 706 for the above-mentioned functions, as shown in Figure 7. Alternatively, the at least one transmission signal generator 708 and the at least one receive signal processor 710 may be included in the at least one controller 706. It is appreciable to those skilled in the art that the arrangement of these functional modules is flexible and may vary depending on the practical needs and/or requirements. The data processing, storage and other relevant control apparatus can be

provided on an appropriate circuit board and/or in chipsets. In various embodiments, when in operation, the at least one radio transmitter 702, at least one radio receiver 704, and at least one antenna 712 may be controlled by the at least one controller 706.

[89] The communication apparatus 700, when in operation, provides functions required for Msg5 Physical Uplink Shared Channel (PUSCH) enhancement. For example, the communication apparatus 700 may be a first communication apparatus or a user equipment. As shown in the exemplified method for Msg5 PUSCH enhancement in Figure 8, the first communication apparatus 700, when in operation, is configured to perform the following steps:

- Step 802: the circuitry 714 (or the at least one controller 706 of the circuitry 714) may determine a plurality of resources for one or more PUSCH transmissions, the one or more PUSCH transmissions indicating that a Radio Resource Control (RRC) setup with a second communication apparatus is completed.
- Step 804: The at least one radio transmitter 702 may perform the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

[90] Additionally or alternatively, in step 802, the circuitry 714 (or the at least one controller 806 of the circuitry 714) may determine the plurality of resources based on control information indicating the plurality of resources or a number of repetitions of the one or more PUSCH transmissions.

[91] Additionally or alternatively, in step 802, the at least one radio transmitter 702 may transmit a request information of the one or more PUSCH transmissions over the plurality of resources to the second communication apparatus, and the at least one radio receiver 704 may receive control information in response to the request information from the second

communication apparatus, and the circuitry 714 (or the at least one controller 706 of the circuitry 714) determines the plurality of resources based on the control information.

[92] For example, the communication apparatus 700 may be a second communication apparatus, a base station or a gNodeB (gNB). As shown in the exemplified method for Msg5 PUSCH enhancement in Figure 9, the second communication apparatus 700, when in operation, is configured to perform the following steps:

- Step 902: the circuitry 714 (or the at least one controller 706 of the circuitry 714) may schedule to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed.
- Step 904: the at least one radio receiver 704 may receive the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

[93] Additionally or alternatively, in step 902, the at least one radio receiver 704 may receive request information of the one or more PUSCH transmissions over the plurality of resources by the first communication apparatus and the circuitry 714 (or the at least one controller 806 of the circuitry 714) schedules to receive the one or more PUSCH transmissions from the first communication apparatus in response to the receipt of the request information.

[94] Additionally or alternatively, in step 902, the circuitry 714 (or the at least one transmission signal generator 708 of the circuitry 714) may generate control information indicating the plurality of resources for the one or more PUSCH transmissions, and the at least one radio transmitter 702 transmits the control information in response to the receipt of the request information.

[95] The present disclosure provides four embodiments to enhance Msg5 PUSCH. The first embodiment may make use of Msg5 PUSCH repetition. The second embodiment may make use of a processing of a single transport block over multiple slots (TBoMS) for Msg5 PUSCH. The third embodiment may make use of repetition of single TboMS for Msg5 PUSCH. The fourth embodiment may make use of joint channel estimation (JCE) applied on top of Msg5 PUSCH repetitions in the first embodiment. The details on realizing these four embodiments are different from that for enabling the existing Msg3 PUSCH repetition or the existing TboMS/JCE for PUSCH and will be described below.

[96] In the following paragraphs, a first embodiment of the present disclosure which relates to Msg5 PUSCH enhancement by making use of Msg5 PUSCH repetition is explained. It is noted that the term “a request for a Msg5 PUSCH repetition” and “a report of capability of Msg5 PUSCH repetition” can be used interchangeably in the present disclosure.

[97] According to the first embodiment of the present disclosure, a UE sends a request information, for example, a request for a Msg5 PUSCH repetition or a repetition number to a gNB, and the gNB which receives the request information sends control information indicating the repetition number of Msg5 PUSCH repetition to the UE. Such request information and/or the control information can be sent or indicated either implicitly or explicitly. Only one of the request information and the control information may be sent explicitly.

[98] The request information, which in this embodiment referring to a request for a Msg5 PUSCH repetition or a repetition number, can be sent by the UE through one or a combination of: (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ

ACK/NACK of a Msg4 PDSCH, and (c) a part of a Msg5 PUSCH repetition. It is noted that this request information is different from that for realizing Msg3 PUSCH repetition. More details on the request information will be described in Figures 13-16 and their accompanying description below.

[99] The control information, which in this embodiment comprising a repetition number of Msg5 PUSCH repetition, can be indicated by the gNB to the UE through one or a combination of: (a) a configuration in Msg4 PDSCH or a system information block (e.g., SIB1), (b) an indication in a DCI scheduling a Msg5 PUSCH repetition, and (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission. It is noted that this control information is different from that for realizing Msg3 PUSCH repetition. More details on the control information will be described in Figure 17 and its accompanying description below.

[100] Figure 10A shows an example format of Msg5 PUSCH 1000 repetition over multiple slots according to the first embodiment of the present disclosure. In this example, a number of repetitions of 4 is indicated for Msg5 PUSCH and thus transmissions of four repetitions of Msg5 PUSCH (Rep#1 of Msg5 PUSCH, Rep#2 of Msg5 PUSCH, Rep#3 of Msg5 PUSCH, Rep#4 of Msg5 PUSCH) are performed on 4 different slots, for example, slot i , slot $i+1$, slot $i+2$ and slot $i+3$, as shown in Figure 10A. It will be appreciated by a person skilled in the art that, throughout the disclosure, the slot number “ i ” may be an integer equal to or larger than 0.

[101] This first embodiment of the present disclosure provides advantages to improve coverage of Msg5 PUSCH by achieving frequency diversity gain and/or time diversity gain. Especially when the control information is indicated by the gNB through an indication in a

DCI scheduling a Msg5 PUSCH repetition, DCI 0_0 with cyclic redundancy check (CRC) scrambled by Radio Network Temporary Identifiers (RNTIs) other than TC-RNTI (e.g., C-RNTI) can be used to schedule initial transmissions of Msg5 PUSCH repetition. This is beneficial to enhance the coverage because of the robustness and small payload size of DCI 0_0. This is also different from that is used for Msg3 PUSCH repetition where DCI 0_0 with CRC scrambled with TC-RNTI can only schedule retransmission of Msg3 PUSCH repetition, however, at least for NTN scenario, retransmission is not a typical way due to its large delay and initial transmission is more desirable. Although DCI 0_0 is mentioned, it is appreciated by a skilled person that either or both DCI 0_0 and DCI format 0_1 are applicable.

[102] It is noted that a transport block (TB) for Msg5 is calculated on the basis of 1 repetition and the TB is processed on the basis of a repetition in a slot, and the TB for Msg5 can be transmitted in multiple repetitions based on concepts of PUSCH with repetition type A or type B (e.g., multiple repetitions in a slot (intra-slot repetition), multiple repetitions in multiple mini-slots (inter-mini-slot repetition), multiple repetitions in multiple slots (inter-slot repetition)). For example, the TB for Msg5 may be repeated in symbol numbers i , $i+1$, $i+2$ and $i+3$ in a slot in intra-slot repetition operation. Further, a number of resources/repetitions used for Msg5 may be different from that used for one or more previous PUSCH transmissions carrying a RRC setup request message (e.g., Msg3). For example, the number of resources/repetitions used for Msg5 may be 4, and that used for one or more previous PUSCH transmissions carrying a RRC setup request message (e.g., Msg3) may be 1. For PUSCH repetition type A, a slot includes a PUSCH repetition of a transport block (TB) and time-domain resource allocations (including a starting OFDM symbol and a length) of the PUSCH repetition of the TB are the same in multiple slots. Hence, the TB is repeatedly transmitted multiple times in multiple slots. It can be considered as a slot-level repetition or inter-slot repetition. For PUSCH repetition type B,

there could be one or more nominal PUSCH repetitions in multiple slots, where each nominal PUSCH repetition can span across consecutive slots. If the nominal PUSCH repetition collides with invalid OFDM symbols of higher priority signal/channel or with a slot boundary, it can be spitted into one or more actual PUSCH repetitions. In this case, one or more actual PUSCH repetitions can be included within a slot, where their own time-domain resource allocations can be different from each other. Hence, PUSCH repetition type B can be considered as mini-slot-level repetition or intra-slot repetition.

[103] Similar to the skilled solution, it is noted that a UE with Msg5 PUSCH repetition capability can also be capable of Msg1 repetition and/or capable of Msg3 PUSCH repetition, that is, if a UE sends a request for a Msg5 PUSCH repetition, it implicitly understand that the UE also request for a Msg3 PUSCH repetition based on this embodiment.

[104] In the following paragraphs, a second embodiment of the present disclosure which relates to Msg5 PUSCH enhancement by making use of a processing of a single transport block over multiple slots (TBoMS) for Msg5 PUSCH is explained.

[105] According to the second embodiment of the present disclosure, a UE sends request information, for example, a request for a processing of a single TBoMS for Msg5 PUSCH to a gNB, and the gNB which receives the request information sends control information indicating at least a number of N slots and a number of resource elements (REs) per slot for doing the single TBoMS to the UE. Such request information and/or the control information can be sent or indicated either implicitly or explicitly. The number of slots ($N \geq 1$) for TBoMS is counted based on available slots for UL transmission as specified in Rel. 17 on PUSCH repetition type A. Only one of the request information and the control information may be sent explicitly.

[106] In particular, for determination of the available slots, the following 2-step operation may be carried out, noting that only *tdd-UL-DL-ConfiguraitonCommon*, *tdd-UL-DL-ConfigurationDedicated* and *ssb-PositionsInBurst* are considered for the determination of available slots:

- Step 1: Determine available slots for K repetitions based on RRC configuration(s) in addition to TDRA in the DCI scheduling the PUSCH, configured grant (CG) configuration or activation DCI.
- Step 2: The UE determines whether to drop a PUSCH repetition or not according to Rel.15 / 16 PUSCH dropping rules, but the PUSCH repetition is still counted in the K repetitions.

[107] It is noted that the number of resource elements can be same or different for different slots. A TB size of the single TBoMS for Msg5 is calculated on the basis of multiple slots and it is processed on the basis of multiple slots, and the TB is transmitted in multiple parts over multiple slots.

[108] The request information, which in this embodiment referring to a request for a processing of a single TBoMS for Msg5 PUSCH, can be sent by the UE through one or a combination of: (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, and (c) a part of a Msg5 PUSCH repetition. It is noted that this request information is different from that for realizing Msg3 PUSCH repetition. More details on the request information will be described in Figures 13-16 and their accompanying description below. Alternatively, it is also possible that the request information is sent by the UE through a separate PRACH resource.

[109] The control information, which in this embodiment comprising at least a number of N slots and a number of resource elements (REs) per slot for doing the single TBoMS, can be indicated by the gNB to the UE through one or a combination of: (a) a configuration in Msg4 PDSCH or a system information block (e.g., SIB1), (b) an indication in a DCI scheduling a Msg5 PUSCH repetition, and (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission. It is noted that this control information is different from that for realizing Msg3 PUSCH repetition. More details on the control information will be described in Figure 17 and its accompanying description below.

[110] Figure 10B shows an example format of a single transport block processing over multiple slots (TBoMs) for Msg5 PUSCH 1010 according to the second embodiment of the present disclosure. Those skilled in the art should understand that the number of slots allocated for TBoMS, N , may be an integer and in this example, N equals 4. As shown in figure 10B, the number of slots of 4 is indicated for Msg5 PUSCH and transmissions of a single TBoMS on 4 slots are performed, where slots are numbered as i , $i + 1$, $i + 2$, $i + 3$, respectively.

[111] This second embodiment of the present disclosure provides advantages to improve coverage of Msg5 PUSCH by increasing the power spectrum density (PSD) and/or achieving channel coding gain due to enlarging the code block length.

[112] In the following paragraphs, a third embodiment of the present disclosure which relates to Msg5 PUSCH enhancement by making use of a processing of a single transport block over multiple slots (TBoMS) and repetitions of the single TBoMS for Msg5 PUSCH is explained.

[113] According to the third embodiment of the present disclosure, a UE sends request information, for example, a joint request for a processing of a single TBoMS and a repetition of a single TBoMS for Msg5 PUSCH to a gNB, and the gNB which receives the request information sends control information indicating at least a number of N slots and a number of REs per slot for doing the single TBoMS, as well as a number of M repetitions of the single TBoMs, to the UE. Such request information and/or the control information can be sent or indicated either implicitly or explicitly. The total number of slots for repetition of the single TBoMS is $M \times N$ slots based on available slots for UL transmission. Only one of the request information and the control information may be sent explicitly.

[114] The request information, which in this embodiment referring to a joint request for a processing of a single TBoMS and a repetition of a single TBoMS for Msg5 PUSCH, can be sent by the UE through one or a combination of: (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, and (c) a part of a Msg5 PUSCH repetition. It is noted that this request information is different from that for realizing Msg3 PUSCH repetition. More details on the request information will be described in Figures 13-16 and their accompanying description below. Alternatively, it is also possible that the request information is sent by the UE through a separate PRACH resource (e.g., Physical Random Access Channel (PRACH) preamble or PRACH occasion).

[115] The control information, which in this embodiment comprising at least a number of N slots and a number of REs per slot for doing the single TBoMS, can be indicated by the gNB to the UE through one or a combination of: (a) a configuration in Msg4 PDSCH or a system information block (e.g., SIB1), (b) an indication in a DCI scheduling a Msg5 PUSCH

repetition, and (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission. It is noted that this control information is different from that for realizing Msg3 PUSCH repetition. More details on the control information will be described in Figure 17 and its accompanying description below.

[116] Figure 11 shows an example format of M repetitions of the single TBoMS for Msg5 PUSCH 1100 according to the third embodiment of the present disclosure. In this example, a number of (N) slots is indicated for TBoMS and a number of (M) repetitions of the TBoMS is also indicated. Transmissions of M repetitions of the single TBoMS are performed, wherein each TboMS is transmitted on N slots and repeatedly M times. Those skilled in the art should understand that the number of slots allocated to each TBoMS, N , may be an integer, and the number of repetitions of the TBoMS, M , may also be an integer.

[117] This third embodiment of the present disclosure provides advantages to improve coverage of Msg5 PUSCH by increasing the power spectrum density (PSD), achieving channel coding gain due to enlarging the code block length and/or achieving frequency/time diversity gain.

[118] In the following paragraphs, a fourth embodiment of the present disclosure which relates to Msg5 PUSCH enhancement by making use of joint channel estimation (JCE) over Msg5 PUSCH repetition described in the first embodiment is explained.

[119] According to the fourth embodiment of the present disclosure, a UE sends request information, for example, a joint request for a request for a Msg5 PUSCH repetition or a repetition number and JCE over Msg5 PUSCH repetition to a gNB, and the gNB which receives

the request information sends control information indicating at least one or more nominal time domain window (TDW) and a repetition number of Msg5 PUSCH repetitions to the UE. Such request information and/or the control information can be sent or indicated either implicitly or explicitly. Only one of the request information and the control information may be sent explicitly.

[120] It is noted that such JCE can be applied on top of the second embodiment and/or the third embodiment, where a JCE over a single TBoMs and/or a repetition of a single TBoMS are requested.

[121] A JCE procedure may be carried out using the following 2-step operation based on Rel. 17 specification:

- Step 1: One or more nominal time domain windows (TDWs) of length L can be configured based on physical slots (for Rel. 15/16 UEs) and based on available slots (for Rel. 17/18 UEs), where L does not exceed a maximum duration reported as UE capability. If one or more nominal TDWs of length L are not configured, a default value of L may be set using the following equation (1).
- Step 2: Within each nominal TDW, one or more actual TDWs are implicitly determined by the UE due to events (e.g., UE beam switching, etc.). It is noted that, during an actual TDW, a phase continuity and a power consistency needs to be maintained by the UE.

Equation (1):

$$L = \min (\text{maximum duration, duration of Msg5 PUSCH repetitions})$$

[122] The request information, which in this embodiment referring to a joint request for a request for a Msg5 PUSCH repetition or a repetition number and JCE over Msg5 PUSCH repetition, can be sent by the UE through one or a combination of: (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, and (c) a part of a Msg5 PUSCH repetition. It is noted that this request information is different from that for realizing Msg3 PUSCH repetition. More details on the request information will be described in Figures 13-16 and their accompanying description below. Alternatively, it is also possible that the request information is sent by the UE through a separate PRACH resource.

[123] The control information, which in this embodiment comprising at least one or more nominal time domain window (TDW) and a repetition number of Msg5 PUSCH repetitions, can be indicated by the gNB to the UE through one or a combination of: (a) a configuration in Msg4 PDSCH or a system information block (e.g., SIB1), (b) an indication in a DCI scheduling a Msg5 PUSCH repetition, and (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission. It is noted that this control information is different from that for realizing Msg3 PUSCH repetition. More details on the control information will be described in Figure 17 and its accompanying description below.

[124] Figure 12 shows an example format of applying joint channel estimation over Msg5 PUSCH repetitions 1200 according to the fourth embodiment of the present disclosure. In this example, a number of repetitions of 4, and a nominal TDW with a length L corresponding to five slots are indicated. The UE (e.g., circuitry of the UE) then determines 4 actual TDWs due to a UE beam switching event on slot number $i + 2$, and the transmissions of Msg5 PUSCH on slot numbers $i, i + 1, i + 3, i + 4$ are performed.

[125] Additionally, if a feature of Msg5 PUSCH repetition is introduced as a mandatory capability, instead of sending the joint request, the UE only needs to send a request of joint channel estimation over Msg5 PUSCH repetitions as a separate request.

[126] This fourth embodiment of the present disclosure provides advantages to improve coverage of Msg5 PUSCH by achieving frequency/time diversity gain and/or a combined decoding gain of JCE (also known as DMRS bundling).

[127] As mentioned above, the request information of various embodiments above can be sent by the UE through one or a combination of: (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, and (c) a part of a Msg5 PUSCH repetition.

[128] In the following paragraphs, request information contained in a part of a Msg3 PUSCH for Msg5 PUSCH enhancement is described, and a request for a Msg5 PUSCH repetition, a repetition number to request for a Msg5 PUSCH repetition, a request for a processing of a single TBoMS, a joint request for a repetition of a single TBoMS of Msg5 PUSCH, and a joint request for JCE over Msg5 PUSCH repetitions are collectively termed as “a request for a Msg5 PUSCH repetition”.

[129] There are five different options to indicate a request for a Msg5 PUSCH repetition in a part of a Msg3 PUSCH: (a) a reserved (R) field in a MAC sub-header of a MAC sub-packet data unit (subPDU) of a Msg3 (carried by Msg3 PUSCH); (b) one reserved (R) field in Logical Channel Identifier (LCID) field in a MAC sub-header of a MAC subPDU of a Msg3 (carried by Msg3 PUSCH); (c) a rule based on interpretation of the reserved R field and one or more

remaining fields in the MAC sub-header of the MAC subPDU of the Msg3; (d) a field in a fixed-size/variable size MAC control element (CE) in a MAC sub-header of a MAC subPDU of a Msg3 (carried by Msg3 PUSCH); and (e) a repurposed spare bit of spare information element (IE) in *RRCSetupRequest* IEs or a repurposed spare field value of *EstablishmentCause* IE in *RRCSetupRequest* (carried by Msg3 PUSCH).

[130] Figure 13 shows an example of using a part of Msg3 PUSCH 1300 to send a request of Msg5 PUSCH enhancement according to an embodiment of the present disclosure. The Msg3 PUSCH 1300 may comprise two MAC subPDUs including MAC SDU (Service Data Unit) 1302, 1304, two MAC subPDUs including MAC CE 1306, 1308 (one 1306 with fixed-size MAC CE 1 and one 1308 with variable-size MAC CE 2), and a MAC subPDU including padding 1310. The MAC subPDUs including MAC SDU 1302, 1304 each may comprise a Reserved/Format/LCID/Length sub-header 1312 and a MAC SDU. The MAC subPDUs including MAC CE 1306, 1308 each may comprise a sub-header and a MAC CE. For the MAC subPDU with fixed-size MAC CE 1306, it comprises a R/LCID sub-header 1314 and a fixed-size MAC CE 1315; whereas for the MAC subPDU with variable-size MAC CE 1308, it comprises a R/F/LCID/L sub-header 1316 and a variable-size MAC CE 1317.

[131] As shown in Figure 13, a R/F/LCID/L sub-header may comprise a reserved (R) field, a format (F) field, a LCID field which are at octet 1 (Oct 1), and a Length (L) field at octet 2 (Oct 2), whereas a R/LCID sub-header comprises a R field and a LCID field.

[132] According to various embodiments described above, the R field, in either R/F/LCID/L sub-header 1312, 1316 or R/LCID sub-header 1314, can be set to indicate a request for a Msg5 PUSCH repetition or a repetition number, and the UE sends the request based on the indication

in the R field, for example, when the R field is set from “0” to “1”. Additionally or alternatively, “1” can be set to request only a minimum (or maximum) repetition number from a set of repetition numbers configured by SIB1 or any preconfigured repetition number. Advantageously, this has no specification impact for physical layer.

[133] Additionally or alternatively, the one R field in LCID field, in either R/F/LCID/L sub-header 1312, 1316 or R/LCID sub-header 1314, can also be set to indicate a request for a Msg5 PUSCH repetition or a repetition number, and the UE sends the request based on the indication in the R field in LCID field, for example, when it is set from “0” to “1”. Figure 14 shows an example table 1400 of LCID values indicated by different codepoints/indices of the R field in LCID field for requesting Msg5 PUSCH enhancement. In this example, index 47 is set from “0” to “1” to request Msg5 PUSCH repetition. For the request of the repetition number, different repetition numbers can be indicated using different tables for values of LCID, and the table in Figure 14 is just one example table for Msg5 PUSCH enhancement. Advantageously, this has no specification impact for physical layer.

[134] Additionally or alternatively, a request for a Msg5 PUSCH repetition or a repetition number can also be signaled according to a rule based on interpretation of the reserved R field and one or more remaining fields such as F field, L field and/or LCID field in the MAC sub-header of the MAC subPDU of the Msg3. For example, if the reserved R field is set as 1 and a different table for values of LCID other than existing Table 6.2.1-2 in TS 38.321 is used, the request is implicitly signalled. The different table for values of LCID can be predefined or configured. Advantageously, this has no specification impact for physical layer.

[135] Additionally or alternatively, a field in the fixed-size/variable size MAC CE 1315, 1317 in the MAC subPDU of the Msg3 (carried by Msg3 PUSCH) can be used to indicate a request for a Msg5 PUSCH repetition. For the request of the repetition number, depending on different sizes of the variable size MAC CE 1317, different repetition number can be requested. Advantageously, this has no specification impact for physical layer.

[136] Additionally or alternatively, a spare bit of spare information element (IE) in *RRCSetupRequest* IEs carried by Msg3 PUSCH (e.g., set from “0” to “1”) or a spare field value (i.e., spare1/2/3/4/5/6) of *EstablishmentCause* IE in *RRCSetupRequest* carried by Msg3 PUSCH (e.g., spare6 is replaced by *Msg5 PUSCHRepetition*) can be repurposed and used to indicate a request for a Msg5 PUSCH repetition or a repetition number. Advantageously, this has no specification impact for physical layer.

[137] Figure 15 shows an example *RRCSetupRequest* information elements (IEs) 1500 carried by a Msg3 for requesting Msg5 PUSCH enhancement according to an embodiment of the present disclosure. Two possible ways to repurpose the *RRCSetupRequest* for Msg5 PUSCH enhancement, indicated as “Possible 1” and “Possible 2 in Figure 15, respectively. In Possible 1, the spare bit of the spare information element 1502 of the *RRCSetupRequest* 1500 can be repurposed, for example, setting from “0” to “1”, to indicate a request for a Msg5 PUSCH repetition or a repetition number. Alternatively, in Possible 2, the spare bit of *EstablishmentCause* IE in the *RRCSetupRequest* 1500 can be repurposed, for example, spare6 is replaced by *Msg5 PUSCHRepetition*, to indicate a request for a Msg5 PUSCH repetition or a repetition number.

[138] It is noted that *EstablishmentCause* provides the establishment cause for the *RRCSetupRequest* in accordance with the information received from upper layers. A gNB is not expected to reject an *RRCSetupRequest* due to unknown cause value being used by the UE, as specified in TS 38.321.

[139] In the following paragraphs, request information contained in a part of a Msg4 PUCCH carrying a HARQ ACK/NACK of a Msg4 PDSCH for Msg5 PUSCH enhancement is described, and a request for a Msg5 PUSCH repetition, a repetition number to request for a Msg5 PUSCH repetition, a request for a processing of a single TBoMS, a joint request for a repetition of a single TBoMS of Msg5 PUSCH, and a joint request for JCE over Msg5 PUSCH repetitions are collectively termed as “a request for a Msg5 PUSCH repetition”. In one example, the request information contained or carried in a part of a Msg4 PUCCH carrying a HARQ ACK/NACK of a Msg4 PDSCH for Msg5 PUSCH may refer to request information which is multiplexed using a resource of the PUCCH carrying a HARQ ACK information of Msg4 PDSCH or the one of the one or more PUSCH transmissions. More information will be provided below.

[140] There are three different options to indicate a request for a Msg5 PUSCH repetition in a part of a PUCCH carrying a HARQ ACK/NACK of a Msg4 PDSCH: (a) a different demodulation reference signal (DMRS) sequence in a PUCCH; (b) the request of the Msg5 PUSCH repetition is multiplexed using on a (dedicated) resource from radio resources of one repetition of Msg5 PUSCH repetitions based on a signaling or a predefined manner; (c) 1-bit indicator for a request of a Msg5 PUSCH repetition and 2-bit UCI based on 1-bit HARQ-ACK and 1 bit-indicator for the request.

[141] A different DMRS sequence in PUCCH (other than the legacy DMRS sequence) can be used as an implicit indication of a request for a Msg5 PUSCH repetition or a repetition number (including cyclic shift, orthogonal code different). For the request of the repetition number, a different DMRS sequence can be used for requesting different repetition number. Advantageously, this is no need of signaling.

[142] Additionally or alternatively, a request, e.g., a request for a Msg5 PUSCH repetition or a repetition number (including cyclic shift, orthogonal code different), is multiplexed by using a (dedicated) resource from radio resources of PUCCH based on a signaling or a predefined manner.

[143] When based on the signaling, the (dedicated) resource can be configured in Msg4 PDSCH such as a UL grant. For example, if a UE requests Msg3 PUSCH repetition, a gNB configures either (a) only resource for UCI as legacy one, or (b) resource for UCI and dedicated resource for requesting a Msg5 PUSCH repetition, in the UL grant. A UE without capability of Msg5 PUSCH repetition uses only resource for UCI as legacy one for sending the PUCCH; whereas a UE with capability of Msg5 PUSCH repetition uses resource for UCI for sending the PUCCH and dedicated resource for sending the request for the Msg5 PUSCH repetition.

[144] When based on the predefined manner, the dedicated resources may be done by puncturing radio resource of PUCCH according to a certain pattern. For the request of the repetition number, punctured resource position and/or the pattern to fill punctured resource can be different depending on the repetition number. For example, if a UE has a Msg5 PUSCH repetition capability, it punctures PUCCH resources by a predefined pattern; whereas if a UE is not capable of Msg5 PUSCH repetition or does not send the request, it does not puncture

PUCCH resource (e.g., 1 dedicated resource shown in Figure 16, for sending the request). If the UE requests Msg3 PUSCH repetition, the gNB performs blind detection whether PUCCH resources are punctured or not for checking the request; whereas if the UE does not request Msg3 PUSCH repetition, the gNB then assumes there is no request for Msg5 PUSCH repetition. Advantageously, there is no need for signaling if the dedicated resource can be determined based on a predefined manner.

[145] Additionally or alternatively the Msg4 PUCCH carrying HARQ ACK/NACK of Msg4 PDSCH may contain a 1-bit indicator for a request of Msg5 PUSCH and 2-bit UCI is generated based on 1-bit HARQ-ACK and 1-bit indicator for the request.

[146] In the following paragraphs, request information contained in a part of a Msg5 PUSCH repetition for Msg5 PUSCH enhancement is described, and a request for a Msg5 PUSCH repetition, a repetition number to request for a Msg5 PUSCH repetition, a request for a processing of a single TBoMS, a joint request for a repetition of a single TBoMS of Msg5 PUSCH, and a joint request for JCE over Msg5 PUSCH repetitions are collectively termed as “a request for a Msg5 PUSCH repetition”.

[147] There are two different options to indicate a request for a Msg5 PUSCH repetition in a part of a Msg5 PUSCH repetition: (a) a DMRS sequence in the Msg5 PUSCH repetition; and (b) the request of the Msg5 PUSCH repetition is multiplexed using on a (dedicated) resource from radio resources of one repetition of Msg5 PUSCH repetitions based on a signaling or a predefined manner.

[148] A different DMRS sequence in the Msg5 PUSCH repetitions can be used as an implicit indication of a request for a Msg5 PUSCH repetition or a repetition number (including cyclic shift, orthogonal code different). For the request of the repetition number, a different DMRS sequence can be used for requesting different repetition number. Advantageously, this is no need of signaling.

[149] Additionally or alternatively, a request, e.g., a request for a Msg5 PUSCH repetition or a repetition number, is multiplexed by using a (dedicated) resource from radio resources of PUCCH based on a signaling or a predefined manner.

[150] When based on the signaling, the (dedicated) resource can be indicated in a DCI scheduling Msg5 PUSCH repetitions. When based on the predefined manner, the dedicated resources can be done by puncturing radio resource of the one repetition according to a certain pattern (e.g., N lower RBs of the 1st repetition of Msg5 PUSCH repetitions) or by reusing a similar concept of resource determination for UCI multiplexing on PUSCH for PUSCH repetition type A/B as specified in current specification. For the request of the repetition number, puncture resource position and/or the pattern to fill punctured resource can be different depending on the repetition number.

[151] For example, the gNB performs blind detection whether the request is multiplexed or not. A UE without capability of Msg5 PUSCH repetition does not transmit the request, whereas a UE with capability of Msg5 PUSCH repetition transmits the request.

[152] For example, without knowledge of UE capability of Msg5 PUSCH repetition, a gNB configures Msg5 PUSCH repetition in Msg4 PDSCH or a DCI scheduling a Msg5 PUSCH

repetition. The gNB also performs blind detection whether the request is multiplexed or not. A UE without capability of Msg5 PUSCH repetition does not understand this configuration and performs single Msg5 PUSCH; whereas a UE with capability of Msg5 PUSCH repetition understands this configuration and transmits a Msg5 PUSCH repetition with the multiplexed request. Advantageously, this is no need of signaling.

[153] As mentioned above, the control information of various embodiments above can be provided by the gNB through one or a combination of: (a) a configuration by Msg4 PDSCH carrying *RRCSetup* message or system information block (SIB), (b) an indication by DCI scheduling a Msg5 PUSCH repetition, (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission.

[154] In the following paragraphs, one or more from a repetition number of a Msg5 PUSCH, a number of slots and a number of REs per slot, a number of M repetitions and the one or more nominal time domain windows comprised in the control information are collectively termed as “a repetition number of Msg5 PUSCH repetition”.

[155] Figure 17 shows an example *RRCSetup* message 1700 carried by Msg4 PDSCH for Msg5 PUSCH enhancement according to an embodiment of the present disclosure. In the *RRCSetup* message 1700, *Msg5PuschRepetition-r19* is added in *RRCSetup* to configure number of Msg5 PUSCH repetitions, starting symbol and length of repetitions in time-domain, starting symbol and length for reporting capability of Msg5 PUSCH repetition. Advantageously, there is no specification impact for physical layer.

[156] An indication in a DCI scheduling a Msg5 PUSCH repetition such as Modulation Coding Scheme (MCS) information field, time domain resource allocations (TDRA) information field, Transmit Power Control (TPC) information field, Channel State Information (CSI) request information field, Frequency Domain Resource Assignment (FDRA) information field and other field in the DCI can provide a repetition number of Msg5 PUSCH repetitions.

[157] In particular, a MCS information field can be reused as that for a case of Msg3 PUSCH repetition to indicate a repetition number of Msg5 PUSCH repetitions. Advantageously, this requires less standardization effort.

[158] A TDRA information field can be repurposed to indicate a repetition number of Msg5 PUSCH repetitions. A new TDRA table can be introduced to indicate repetition numbers, and it can be configured by SIB1 or Msg4 PDSCH. The new TDRA table may include separate new entry (or indicator) indicating K_2 , mapping type, Start and Length Indicator (SLIV) and repetition number. Alternatively, the new TDRA may include legacy TDRA table (indicating K_2 , mapping type and SLIV) and additional entry indicating repetition number. If the new TDRA table is not configured, the legacy default TDRA table is used and single Msg5 PUSCH (i.e., no repetition) is applied. Advantageously, this has no specification impact on current configuration of Msg3 PUSCH repetition.

[159] A TPC information field can be repurposed to indicate a repetition number of Msg5 PUSCH repetitions. For example, X MSB/LSB bits of the TPC information field can be used, where X can be an integer greater than 1. Alternatively, a predefined TPC command table including repetition number may be introduced. Advantageously, this has no specification impact on current configuration of Msg3 PUSCH repetition.

[160] A CSI request information field can be repurposed to indicate a repetition number of Msg5 PUSCH repetitions. For example, X MSB/LSB bits of the CSI request information field can be used, where X can be an integer greater than 1. Alternatively, a predefined CSI command table including repetition number may be introduced. Advantageously, this has no specification impact on current configuration of Msg3 PUSCH repetition.

[161] A FDRA information field can be repurposed to indicate a repetition number of Msg5 PUSCH repetition. For example, X MSB/LSB bits of the FDRA information field can be used, where X can be an integer greater than 1. Alternatively, a predefined FDRA command table including repetition number may be introduced. Advantageously, this has no specification impact on current configuration of Msg3 PUSCH repetition.

[162] Other field in the DCI scheduling a Msg5 PUSCH repetition can also be repurposed to indicate a repetition number of Msg5 PUSCH repetitions. Advantageously, this has no specification impact on current configuration of Msg3 PUSCH repetition.

[163] Alternatively or additionally, the repetition number of Msg5 PUSCH repetitions is predefined for an initial transmission, while it is indicated by a DCI for a retransmission. For the initial transmission, it is predefined in specifications. For example, 4 repetition numbers of Msg3 PUSCH, which are specified in the specifications, can be used for Msg5 PUSCH repetitions. Additionally, the repetition numbers of Msg3 PUSCH repetition of 4 can be further adjusted for Msg4 PUSCH repetition by applying a scaling factor (e.g., increased by 2 times, etc.). Advantageously, this is no need of signaling for initial transmission.

[164] Figure 18 shows a flowchart 1800 illustrating a communication method implemented by a UE for enabling a Msg5 PUSCH repetition according to various embodiments of the present disclosure. The method may start with step 1802. In step 1802, a step of sending a request of a Msg5 PUSCH repetition or a repetition number is carried out. The request is in (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, (c) a part of a Msg5 PUSCH repetition or a combination thereof. In step 1804, a step of determining a repetition number (N) of a Msg5 PUSCH repetition from (a) a configuration by a Msg4 PUSCH, (b) an indication by a DCI scheduling a Msg5 PUSCH repetition, (c) a predefined number for an initial transmission and an indication by a DCI for a retransmission, or a combination thereof. In step 1806, a step of transmitting N repetitions of Msg5 PUSCH is carried out.

[165] Figure 19 shows a flowchart 1900 illustrating a communication method implemented by a gNB for enabling a Msg5 PUSCH repetition according to various embodiments of the present disclosure. The method may start with step 1902. In step 1902, a step of receiving a request of Msg5 PUSCH repetition or a repetition number is carried out. The request being sent through (a) a part of a Msg3 PUSCH, (b) a part of a Msg4 PUCCH/UCI carrying a HARQ ACK/NACK of a Msg4 PDSCH, (c) a part of a Msg4 PUSCH repetition, or a combination thereof. In step 1904, a step of scheduling a Msg5 PUSCH repetition and providing a repetition number using (a) a configuration by a Msg4 PDSCH, (b) an indication by a DCI scheduling a Msg5 PUSCH repetition, (c) a repetition number predefined for an initial transmission or indicated by a DCI for a retransmission.

[166] Figure 20 shows a diagram 2000 illustrating an example of a RACH procedure, which shows how a RRC setup is performed, between a UE and a gNB, as well as of showing steps

for enabling Msg5 PUSCH repetition according to an embodiment of the present disclosure. In this example, a request of a Msg5 PUSCH repetition and a repetition number for the Msg5 PUSCH repetition are separately indicated. In step 2002, the UE sends a preamble to the gNB. In step 2004, the gNB sends a Msg2 random access response (RAR) to the UE. In step 2006, the UE sends a Msg3 PUSCH to the gNB to request for a RRC setup, where a request of Msg5 PUSCH repetition comprised in a part of the Msg3 PUSCH. In step 2008, the gNB then sends a Msg4 PDSCH carrying a *RRCSetup* message to the UE to indicate a RRC setup. In step 2010, the UE sends a Msg4 PUCCH carrying a Msg4 HARQ-ACK to the gNB. In step 2012, the gNB sends a DCI/PDCCH to schedule a Msg5 PUSCH repetition and indicate a repetition number (N). The UE receives and decodes the DCI to determine a repetition number (N) of the Msg5 PUSCH repetition. In step 2014, the UE then transmits N repetitions of a Msg5 PUSCH accordingly.

[167] Additionally, where DCI is mentioned in the embodiments above, either or both DCI 0_0 and DCI format 0_1 are applicable. The various embodiments above are applicable for PUSCH carrying *RRCSetupComplete* after MsgB in 2-step RACH procedure. The various embodiments above are applicable for PUSCH carrying (general) report of UE capability information (e.g., after Msg5 PUSCH). The various embodiments above are applicable for both contention-based random access (CBRA) and contention-free random access (CFRA) operations.

[168] According to the present disclosure, various examples below have been described:

1. A first communication apparatus comprising:

circuitry, which in operation, determines a plurality of resources for one or more PUSCH (Physical Uplink Shared Channel) transmissions, the one or more PUSCH transmissions indicating that a Radio Resource Control (RRC) setup with a second communication apparatus is completed; and

a transmitter, which in operation, performs the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

2. The first communication apparatus of example 1, wherein the circuitry determines the plurality of resources based on control information, the control information indicating the plurality of resources or a number of repetitions of the one or more PUSCH transmissions.

3. The first communication apparatus of example 2, wherein the control information indicates a number of repetitions of a single TBoMS, and the transmitter transmits repeatedly the single TBoMS for the number of repetitions to the second communication apparatus.

4. The first communication apparatus of example 2, wherein the transmitter transmits a request information of the plurality of resources for the one or more PUSCH transmissions to the second communication apparatus, and the first communication apparatus further comprises:

a receiver, which in operation, receives the control information in response to the request information from the second communication apparatus.

5. The first communication apparatus of example 4, wherein the request information is a request to perform the one or more PUSCH transmissions on the plurality of resources, wherein the one or more PUSCH transmissions corresponds to a number of repetitions of a

same transport block (TB), and the control information indicates a number of the repetitions of the same TB, and wherein the circuitry determines the plurality of resources based on the number of repetitions of the same TB.

6. The first communication apparatus of example 5, wherein the circuitry further determines that one repetition of the repetitions of the same TB collides with a slot boundary and/or a higher priority signal and/or a higher priority channel and, in response to the determination of the collision, splits the one repetition into one or more actual repetitions, wherein the one or more PUSCH transmissions corresponds to the one or more actual repetitions of the same TB.

7. The first communication apparatus of example 4, wherein the request information comprises a number of repetitions of the one or more PUSCH transmissions, and the circuitry determines the plurality of resources based on the control information.

8. The first communication apparatus of example 4, wherein the request information is a request for a processing of a single transport block over multiple slots (TBoMS) transmitted on the plurality of resources to the second communication apparatus, and the control information indicates the plurality of resources for the single TBoMS, and

wherein the circuitry further determines the plurality of resources based on the control information, and the transmitter transmits the single TBoMS for the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

9. The first communication apparatus of any one of examples 4-8, wherein the request information is a request for enabling a joint channel estimation over the one or more PUSCH

transmissions to the second communication apparatus, and the control information indicates one or more nominal time domain windows, and

wherein the circuitry further determines a length of each of one or more actual time domain windows within each of the one or more nominal time domain windows, and generates a part of the one or more PUSCH transmissions to be transmitted on one or more of the plurality of resources based on the length of the each of the one or more actual time domain windows within the each of the one or more nominal time domain windows, and the transmitter transmits the part of the one or more PUSCH transmissions on the one or more of the plurality of resources during the each of the one or more actual time domain window to the second communication apparatus, wherein during the each of the one or more actual time domain windows, a phase continuity and a power consistency of the part of the one or more PUSCH transmissions are maintained.

10. The first communication apparatus of any one of examples 4-9, wherein the request information is indicated by any one or a combination of: (i) one or more information fields of a Msg3 Physical Uplink Shared Channel (PUSCH) carrying a RRC setup request message, (ii) a demodulation reference signal (DMRS) sequence of a Physical Uplink Control Channel (PUCCH) carrying a hybrid automatic repeat request acknowledgement (HARQ ACK) information of a Msg4 Physical Downlink Shared Channel (PDSCH), and (iii) a DMRS sequence of the one or more PUSCH transmissions.

11. The first communication apparatus of any one of examples 4-9, wherein the request information is carried in a PUCCH carrying a HARQ ACK information of a Msg4 PDSCH or in one of the one or more PUSCH transmissions.

12. The first communication apparatus of any one of examples 2-11, wherein the control information is indicated by anyone or a combination of: (i) a configuration of a Msg4 PDSCH carrying a RRC setup message, (ii) a system information block (SIB), and (iii) downlink channel information scheduling the one or more PUSCH transmissions.
13. The first communication apparatus of example 12, wherein the downlink channel information (DCI) scheduling the one or more PUSCH transmissions is either DCI format 0_0 or DCI format 0_1.
14. The first communication apparatus of any one of examples 1-13, wherein the plurality of resources comprise time domain resources including multiple symbols or multiple slots.
15. The first communication apparatus of any one of examples 1-14, wherein the circuitry determines a number of the plurality of resources for the one or more PUSCH transmissions based on a fixed number or a pre-defined number.
16. The first communication apparatus of any one of examples 1-15, the plurality of resources comprises a number of resources which is different from that used for one or more previous PUSCH transmissions carrying a RRC setup request message, the different number of resources used for the one or more previous PUSCH transmissions being one or more than one.
17. The first communication apparatus of any one of examples 1-16, wherein the one or more PUSCH transmissions indicate a report of UE capability information.

18. A second communication apparatus comprising:

circuitry, which in operation, schedules to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed; and

a receiver, which in operation, receives the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

19. The second communication apparatus of example 18, wherein the receiver further receives a request information of the one or more PUSCH transmissions over the plurality of resources by the first communication apparatus; wherein the circuitry schedules to receive the one or more PUSCH transmissions from the first communication apparatus in response to the receipt of the request information.

20. The second communication apparatus of example 19, wherein circuitry generates control information indicating the plurality of resources for the one or more PUSCH transmissions, and
the second communication apparatus further comprising:

a transmitter, which in operation, transmits the control information in response to the receipt of the request information.

21. The second communication apparatus of example 20, wherein the control information is indicated by any one or a combination of: (i) a configuration of a Msg4 PDSCH carrying a RRC setup message, (ii) or a SIB, and (iii) downlink channel information scheduling the one or more PUSCH transmissions.

22. A communication method implemented by a first communication apparatus, comprising:

determining a plurality of resources for one or more PUSCH transmissions, the one or more PUSCH transmissions indicating that a RRC setup with a second communication apparatus is completed; and

performing the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus

23. A communication method implemented by a second communication apparatus, comprising:

scheduling to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed; and

receiving the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

[169] In the following paragraphs, certain exemplifying embodiments are explained with reference to terms related to 5G core network and the present disclosure regarding communication apparatuses and methods for allocating one or more additional operating windows between two semi-statically configured SL DRX cycles for a reception or a transmission of a SL signal, namely:

Control Signals

[170] In the present disclosure, the downlink control signal (information) related to the present disclosure may be a signal (information) transmitted through PDCCH of the physical

layer or may be a signal (information) transmitted through a MAC Control Element (CE) of the higher layer or the RRC. The downlink control signal may be a pre-defined signal (information).

[171] The uplink control signal (information) related to the present disclosure may be a signal (information) transmitted through PUCCH of the physical layer or may be a signal (information) transmitted through a MAC CE of the higher layer or the RRC. Further, the uplink control signal may be a pre-defined signal (information). The uplink control signal may be replaced with uplink control information (UCI), the 1st stage sidelink control information (SCI) or the 2nd stage SCI.

Base Station

[172] In the present disclosure, the base station may be a Transmission Reception Point (TRP), a clusterhead, an access point, a Remote Radio Head (RRH), an eNodeB (eNB), a gNodeB (gNB), a Base Station (BS), a Base Transceiver Station (BTS), a base unit or a gateway, for example. Further, in sidelink communication, a terminal may be adopted instead of a base station. The base station may be a relay apparatus that relays communication between a higher node and a terminal. The base station may be a roadside unit as well.

Uplink/Downlink/Sidelink

[173] The present disclosure may be applied to any of uplink, downlink and sidelink.

[174] The present disclosure may be applied to, for example, uplink channels, such as PUSCH, PUCCH, and PRACH, downlink channels, such as PDSCH, PDCCH, and PBCH, and side link channels, such as Physical Sidelink Shared Channel (PSSCH), Physical Sidelink Control Channel (PSCCH), and Physical Sidelink Broadcast Channel (PSBCH).

[175] PDCCH, PDSCH, PUSCH, and PUCCH are examples of a downlink control channel, a downlink data channel, an uplink data channel, and an uplink control channel, respectively. PSCCH and PSSCH are examples of a sidelink control channel and a sidelink data channel, respectively. PBCH and PSBCH are examples of broadcast channels, respectively, and PRACH is an example of a random access channel.

Data Channels/Control Channels

[176] The present disclosure may be applied to any of data channels and control channels. The channels in the present disclosure may be replaced with data channels including PDSCH, PUSCH and PSSCH and/or control channels including PDCCH, PUCCH, PBCH, PSCCH, and PSBCH.

Reference Signals

[177] In the present disclosure, the reference signals are signals known to both a base station and a mobile station and each reference signal may be referred to as a Reference Signal (RS) or sometimes a pilot signal. The reference signal may be any of a DMRS, a Channel State Information – Reference Signal (CSI-RS), a Tracking Reference Signal (TRS), a Phase

Tracking Reference Signal (PTRS), a Cell-specific Reference Signal (CRS), and a Sounding Reference Signal (SRS).

Time Intervals

[178] In the present disclosure, time resource units are not limited to one or a combination of slots and symbols, and may be time resource units, such as frames, super-frames, subframes, slots, time slot sub-slots, mini-slots, or time resource units, such as symbols, Orthogonal Frequency Division Multiplexing (OFDM) symbols, Single Carrier-Frequency Division Multiplexing Access (SC-FDMA) symbols, or other time resource units. The number of symbols included in one slot is not limited to any number of symbols exemplified in the embodiment(s) described above, and may be other numbers of symbols.

Frequency Bands

[179] The present disclosure may be applied to any of a licensed band and an unlicensed band.

Communication

[180] The present disclosure may be applied to any of communication between a base station and a terminal (Uu-link communication), communication between a terminal and a terminal (Sidelink communication), and Vehicle to Everything (V2X) communication. The channels in the present disclosure may be replaced with PSCCH, PSSCH, Physical Sidelink Feedback Channel (PSFCH), PSBCH, PDCCH, PUCCH, PDSCH, PUSCH, and PBCH.

[181] In addition, the present disclosure may be applied to any of a terrestrial network or a network other than a terrestrial network (NTN: Non-Terrestrial Network) using a satellite or a High Altitude Pseudo Satellite (HAPS). In addition, the present disclosure may be applied to a network having a large cell size, and a terrestrial network with a large delay compared with a symbol length or a slot length, such as an ultra-wideband transmission network.

Antenna Ports

[182] An antenna port refers to a logical antenna (antenna group) formed of one or more physical antenna(s). That is, the antenna port does not necessarily refer to one physical antenna and sometimes refers to an array antenna formed of multiple antennas or the like. For example, it is not defined how many physical antennas form the antenna port, and instead, the antenna port is defined as the minimum unit through which a terminal is allowed to transmit a reference signal. The antenna port may also be defined as the minimum unit for multiplication of a precoding vector weighting.

[183] The present disclosure can be realized by software, hardware, or software in cooperation with hardware. Each functional block used in the description of each embodiment described above can be partly or entirely realized by an LSI such as an integrated circuit, and each process described in each embodiment may be controlled partly or entirely by the same LSI or a combination of LSIs. The LSI may be individually formed as chips, or one chip may be formed so as to include a part or all of the functional blocks. The LSI may include a data input and output coupled thereto. The LSI here may be referred to as an IC, a system LSI, a super LSI, or an ultra LSI depending on a difference in the degree of integration. However, the

technique of implementing an integrated circuit is not limited to the LSI and may be realized by using a dedicated circuit, a general-purpose processor, or a special-purpose processor. In addition, a FPGA (Field Programmable Gate Array) that can be programmed after the manufacture of the LSI or a reconfigurable processor in which the connections and the settings of circuit cells disposed inside the LSI can be reconfigured may be used. The present disclosure can be realized as digital processing or analogue processing. If future integrated circuit technology replaces LSIs as a result of the advancement of semiconductor technology or other derivative technology, the functional blocks could be integrated using the future integrated circuit technology. Biotechnology can also be applied.

[184] The present disclosure can be realized by any kind of apparatus, device or system having a function of communication, which is referred to as a communication apparatus.

[185] The communication apparatus may comprise a transceiver and processing/control circuitry. The transceiver may comprise and/or function as a receiver and a transmitter. The transceiver, as the transmitter and receiver, may include an RF (radio frequency) module including amplifiers, RF modulators/demodulators and the like, and one or more antennas.

[186] Some non-limiting examples of such a communication apparatus include a phone (e.g., cellular (cell) phone, smart phone), a tablet, a personal computer (PC) (e.g., laptop, desktop, netbook), a camera (e.g., digital still/video camera), a digital player (digital audio/video player), a wearable device (e.g., wearable camera, smart watch, tracking device), a game console, a digital book reader, a telehealth/telemedicine (remote health and medicine) device, and a vehicle providing communication functionality (e.g., automotive, airplane, ship), and various combinations thereof.

[187] The communication apparatus is not limited to be portable or movable, and may also include any kind of apparatus, device or system being non-portable or stationary, such as a smart home device (e.g., an appliance, lighting, smart meter, control panel), a vending machine, and any other “things” in a network of an “Internet of Things (IoT)”.

[188] The communication may include exchanging data through, for example, a cellular system, a wireless LAN system, a satellite system, etc., and various combinations thereof.

[189] The communication apparatus may comprise a device such as a controller or a sensor which is coupled to a communication device performing a function of communication described in the present disclosure. For example, the communication apparatus may comprise a controller or a sensor that generates control signals or data signals which are used by a communication device performing a communication function of the communication apparatus.

[190] The communication apparatus also may include an infrastructure facility, such as a base station, an access point, and any other apparatus, device or system that communicates with or controls apparatuses such as those in the above non-limiting examples.

[191] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present disclosure as shown in the specific embodiments without departing from the spirit or scope of the disclosure as broadly described. The present embodiments are, therefore, to be considered in all respects illustrative and not restrictive.

CLAIMS

1. A first communication apparatus comprising:

circuitry, which in operation, determines a plurality of resources for one or more PUSCH (Physical Uplink Shared Channel) transmissions, the one or more PUSCH transmissions indicating that a Radio Resource Control (RRC) setup with a second communication apparatus is completed; and

a transmitter, which in operation, performs the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.
2. The first communication apparatus of claim 1, wherein the circuitry determines the plurality of resources based on control information, the control information indicating the plurality of resources or a number of repetitions of the one or more PUSCH transmissions.
3. The first communication apparatus of claim 2 , wherein the control information indicates a number of repetitions of a single TBoMS, and the transmitter transmits repeatedly the single TBoMS for the number of repetitions to the second communication apparatus.
4. The first communication apparatus of claim 2, wherein the transmitter transmits a request information of the plurality of resources for the one or more PUSCH transmissions to the second communication apparatus, and the first communication apparatus further comprises:

a receiver, which in operation, receives the control information in response to the request information from the second communication apparatus.

5. The first communication apparatus of claim 4, wherein the request information is a request to perform the one or more PUSCH transmissions on the plurality of resources, wherein the one or more PUSCH transmissions corresponds to a number of repetitions of a same transport block (TB), and the control information indicates a number of the repetitions of the same TB, and wherein the circuitry determines the plurality of resources based on the number of repetitions of the same TB.

6. The first communication apparatus of claim 5, wherein the circuitry further determines that one repetition of the repetitions of the same TB collides with a slot boundary and/or a higher priority signal and/or a higher priority channel and, in response to the determination of the collision, splits the one repetition into one or more actual repetitions, wherein the one or more PUSCH transmissions corresponds to the one or more actual repetitions of the same TB.

7. The first communication apparatus of claim 4, wherein the request information comprises a number of repetitions of the one or more PUSCH transmissions, and the circuitry determines the plurality of resources based on the control information.

8. The first communication apparatus of claim 4, wherein the request information is a request for a processing of a single transport block over multiple slots (TBoMS) transmitted on the plurality of resources to the second communication apparatus, and the control information indicates the plurality of resources for the single TBoMS, and

wherein the circuitry further determines the plurality of resources based on the control information, and the transmitter transmits the single TBoMS for the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus.

9. The first communication apparatus of any one of claims 4 to 8, wherein the request information is a request for enabling a joint channel estimation over the one or more PUSCH transmissions to the second communication apparatus, and the control information indicates one or more nominal time domain windows, and

wherein the circuitry further determines a length of each of one or more actual time domain windows within each of the one or more nominal time domain windows, and generates a part of the one or more PUSCH transmissions to be transmitted on one or more of the plurality of resources based on the length of the each of the one or more actual time domain windows within the each of the one or more nominal time domain windows, and the transmitter transmits the part of the one or more PUSCH transmissions on the one or more of the plurality of resources during the each of the one or more actual time domain window to the second communication apparatus, wherein during the each of the one or more actual time domain windows, a phase continuity and a power consistency of the part of the one or more PUSCH transmissions are maintained.

10. The first communication apparatus of any one of claims 4 to 9, wherein the request information is indicated by any one or a combination of: (i) one or more information fields of a Msg3 Physical Uplink Shared Channel (PUSCH) carrying a RRC setup request message, (ii) a demodulation reference signal (DMRS) sequence of a Physical Uplink Control Channel (PUCCH) carrying a hybrid automatic repeat request acknowledgement (HARQ ACK) information of a Msg4 Physical Downlink Shared Channel (PDSCH), and (iii) a DMRS sequence of the one or more PUSCH transmissions.

11. The first communication apparatus of any one of claims 4 to 9, wherein the request information is carried in a PUCCH carrying a HARQ ACK information of a Msg4 PDSCH or in one of the one or more PUSCH transmissions.

12. The first communication apparatus of any one of claims 2 to 11, wherein the control information is indicated by anyone or a combination of: (i) a configuration of a Msg4 PDSCH carrying a RRC setup message, (ii) a system information block (SIB), and (iii) downlink channel information scheduling the one or more PUSCH transmissions.

13. The first communication apparatus of any one of claims 1 to 12, wherein the plurality of resources comprise time domain resources including multiple symbols or multiple slots.

14. The first communication apparatus of any one of claims 1 to 13, the plurality of resources comprises a number of resources which is different from that used for one or more previous PUSCH transmissions carrying a RRC setup request message, the different number of resources used for the one or more previous PUSCH transmissions being one or more than one.

15. A second communication apparatus comprising:

circuitry, which in operation, schedules to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed; and

a receiver, which in operation, receives the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.

16. The second communication apparatus of claim 15, wherein the receiver further receives a request information of the one or more PUSCH transmissions over the plurality of resources by the first communication apparatus; wherein the circuitry schedules to receive the one or more PUSCH transmissions from the first communication apparatus in response to the receipt of the request information.

17. The second communication apparatus of claim 16, wherein circuitry generates control information indicating the plurality of resources for the one or more PUSCH transmissions, and
the second communication apparatus further comprising:

a transmitter, which in operation, transmits the control information in response to the receipt of the request information.

18. The second communication apparatus of claim 17, wherein the control information is indicated by any one or a combination of: (i) a configuration of a Msg4 PDSCH carrying a RRC setup message, (ii) or a SIB, and (iii) downlink channel information scheduling the one or more PUSCH transmissions.

19. A communication method implemented by a first communication apparatus, comprising:

determining a plurality of resources for one or more PUSCH transmissions, the one or more PUSCH transmissions indicating that a RRC setup with a second communication apparatus is completed; and

performing the one or more PUSCH transmissions on the plurality of resources to the second communication apparatus

20. A communication method implemented by a second communication apparatus, comprising:

scheduling to receive one or more PUSCH transmissions from a first communication apparatus, the one or more PUSCH transmissions indicating that a RRC setup with the second communication apparatus is completed; and

receiving the one or more PUSCH transmissions on a plurality of resources from the first communication apparatus.