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User equipments, base stations and signaling for relaxed uplink processing time

Abstract

A user equipment (UE) is described. The UE receives an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The UE receives an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission. The UE receives an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time. The UE receives an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The UE transmits, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X.

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Background/Summary

TECHNICAL FIELD
(1) The present disclosure relates generally to communication systems. More specifically, the present disclosure relates to user equipments, base stations and signaling for relaxed uplink processing time.
BACKGROUND ART
(2) Wireless communication devices have become smaller and more powerful in order to meet consumer needs and to improve portability and convenience. Consumers have become dependent upon wireless communication devices and have come to expect reliable service, expanded areas of coverage and increased functionality. A wireless communication system may provide communication for a number of wireless communication devices, each of which may be serviced by a base station. A base station may be a device that communicates with wireless communication devices.
(3) As wireless communication devices have advanced, improvements in communication capacity, speed, flexibility and/or efficiency have been sought. However, improving communication capacity, speed, flexibility, and/or

efficiency may present certain problems.
(4) For example, wireless communication devices may communicate with one or more devices using a communication structure. However, the communication structure used may only offer limited flexibility and/or efficiency. As illustrated by this discussion, systems and methods that improve communication flexibility and/or efficiency may be beneficial.

SUMMARY OF INVENTION

(5) In one example, a user equipment (UE) that communicates with a base station apparatus, comprising: receiving circuitry configured to: receive a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; receive an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; receive an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; and receive an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and transmitting circuitry configured to transmit, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol X being defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.
(6) In one example, a user equipment (UE) that communicates with a base station apparatus, comprising: receiving circuitry configured to: receive a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; and receive an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; and transmitting circuitry configured to transmit, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X, slot or sub-slot X being defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.
(7) In one example, a base station apparatus that communicates with a user equipment (UE), comprising: transmitting circuitry configured to: transmit a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; transmit an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; transmit an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; and transmit an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and receiving circuitry configured to receive, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol X being defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.
(8) In one example, a base station apparatus that communicates with a user equipment (UE), comprising: transmitting circuitry configured to: transmit a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; and transmit an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; and receiving circuitry configured to receive, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X, slot or sub-slot X being defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.
(9) In one example, a communication method of a user equipment (UE) that communicates with a base station apparatus, comprising: receiving a radio resource control (RRC) message comprising first information used for

indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; receiving an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; receiving an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; receiving an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and transmitting, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol X being defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(10) In one example, a communication method of a user equipment (UE) that communicates with a base station apparatus, comprising: receiving a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; receiving an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; and transmitting, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X, slot or sub-slot X being defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(11) In one example, a communication method of a base station apparatus that communicates with a user equipment (UE), comprising: transmitting a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; transmitting an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; transmitting an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; transmitting an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and receiving, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol X being defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(12) In one example, a communication method of a base station apparatus that communicates with a user equipment (UE), comprising: transmitting a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; transmitting an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; and receiving, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X, slot or sub-slot X being defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. **1** is a block diagram illustrating one implementation of one or more base stations (gNBs) and one or more user equipments (UEs) for relaxed uplink processing time.

(2) FIG. **2** is a diagram illustrating an example of a resource grid for the downlink.

(3) FIG. **3** is a diagram illustrating one example of a resource grid for the uplink.

(4) FIG. **4** shows examples of several numerologies.

(5) FIG. **5** shows examples of subframe structures for the numerologies that are shown in FIG. **4**.

(6) FIG. **6** shows examples of slots and sub-slots.

(7) FIG. **7** shows examples of scheduling timelines.

(8) FIG. **8** shows examples of DL control channel monitoring regions.
(9) FIG. **9** shows examples of DL control channel which includes more than one control channel elements.
(10) FIG. **10** shows examples of UL control channel structures.
(11) FIG. **11** is a block diagram illustrating one implementation of a gNB.
(12) FIG. **12** is a block diagram illustrating one implementation of a UE.
(13) FIG. **13** illustrates various components that may be utilized in a UE.
(14) FIG. **14** illustrates various components that may be utilized in a gNB.
(15) FIG. **15** is a block diagram illustrating one implementation of a UE in which systems and methods for relaxed uplink processing time may be implemented.
(16) FIG. **16** is a block diagram illustrating one implementation of a gNB in which systems and methods for relaxed uplink processing time may be implemented.
(17) FIG. **17** is a flow diagram illustrating a method by a UE.
(18) FIG. **18** is a flow diagram illustrating a method by gNB.
(19) FIG. **19** is a flow diagram illustrating a method by a UE.
(20) FIG. **20** is a flow diagram illustrating a method by gNB.

DESCRIPTION OF EMBODIMENTS

(21) A user equipment (UE) that communicates with a base station apparatus is described. The UE includes receiving circuitry configured to receive a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; to receive an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; to receive an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; and to receive an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The UE also includes transmitting circuitry configured to transmit, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X. Symbol X is defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(22) Another UE that communicates with a base station apparatus is described. The UE includes receiving circuitry configured to receive an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; and to receive an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The UE also includes transmitting circuitry configured to transmit, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at slot or sub-slot X. The Slot or sub-slot X is defined as the next slot or sub-slot with uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(23) A base station apparatus that communicates with a UE is also described. The base station apparatus includes transmitting circuitry configured to transmit an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; to transmit an RRC message comprising second information used for indicating a numerology for a PUSCH transmission; to transmit an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; and to transmit an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The base station apparatus also includes receiving circuitry configured to receive, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at symbol X. Symbol X is defined as the next uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(24) Another base station apparatus that communicates with a UE is described. The base station apparatus includes transmitting circuitry configured to transmit an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; and to transmit an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The base station apparatus also includes receiving circuitry configured to receive, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at slot or sub-slot X. The slot or sub-slot X is defined as the next slot or sub-slot with uplink symbol with its CP starting

T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(25) A communication method of a UE that communicates with a base station apparatus is also described. The method includes receiving an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The method also includes receiving an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The method further includes receiving an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time. The method additionally includes receiving an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The method also includes transmitting, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at symbol X. The symbol X is defined as the next uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(26) Another communication method of a UE that communicates with a base station apparatus is described. The method includes receiving an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The method also includes receiving an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The method further includes transmitting, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at slot or sub-slot X. The slot or sub-slot X is defined as the next slot or sub-slot with uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(27) A communication method of a base station apparatus that communicates with a UE is also described. The method includes transmitting an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The method also includes transmitting an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The method further includes transmitting an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time. The method additionally includes transmitting an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The method also includes receiving, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at symbol X. Symbol X is defined as the next uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

(28) Another communication method of a base station apparatus that communicates with a UE is also described. The method includes transmitting an RRC message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The method also includes transmitting an RRC message comprising second information used for indicating a numerology for a PUSCH transmission. The method further includes receiving, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a DM-RS is no earlier than at slot or sub-slot X. The slot or sub-slot X is defined as the next slot or sub-slot with uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the PDCCH carrying a DCI scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(29) The 3rd Generation Partnership Project, also referred to as “3GPP,” is a collaboration agreement that aims to define globally applicable technical specifications and technical reports for third and fourth generation wireless communication systems. The 3GPP may define specifications for next generation mobile networks, systems and devices.

(30) 3GPP Long Term Evolution (LTE) is the name given to a project to improve the Universal Mobile Telecommunications System (UMTS) mobile phone or device standard to cope with future requirements. In one aspect, UMTS has been modified to provide support and specification for the Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN).

(31) At least some aspects of the systems and methods disclosed herein may be described in relation to the 3GPP LTE, LTE-Advanced (LTE-A) and other standards (e.g., 3GPP Releases 8, 9, 10, 11 and/or 12). However, the scope of the present disclosure should not be limited in this regard. At least some aspects of the systems and methods

disclosed herein may be utilized in other types of wireless communication systems.
(32) A wireless communication device may be an electronic device used to communicate voice and/or data to a base station, which in turn may communicate with a network of devices (e.g., public switched telephone network (PSTN), the Internet, etc.). In describing systems and methods herein, a wireless communication device may alternatively be referred to as a mobile station, a UE, an access terminal, a subscriber station, a mobile terminal, a remote station, a user terminal, a terminal, a subscriber unit, a mobile device, etc. Examples of wireless communication devices include cellular phones, smart phones, personal digital assistants (PDAs), laptop computers, netbooks, e-readers, wireless modems, etc. In 3GPP specifications, a wireless communication device is typically referred to as a UE. However, as the scope of the present disclosure should not be limited to the 3GPP standards, the terms “UE” and “wireless communication device” may be used interchangeably herein to mean the more general term “wireless communication device.” A UE may also be more generally referred to as a terminal device.
(33) In 3GPP specifications, a base station is typically referred to as a Node B, an evolved Node B (eNB), a home enhanced or evolved Node B (HeNB) or some other similar terminology. As the scope of the disclosure should not be limited to 3GPP standards, the terms “base station,” “Node B,” “eNB,” “gNB” and/or “HeNB” may be used interchangeably herein to mean the more general term “base station.” Furthermore, the term “base station” may be used to denote an access point. An access point may be an electronic device that provides access to a network (e.g., Local Area Network (LAN), the Internet, etc.) for wireless communication devices. The term “communication device” may be used to denote both a wireless communication device and/or a base station. An eNB may also be more generally referred to as a base station device.
(34) It should be noted that as used herein, a “cell” may be any communication channel that is specified by standardization or regulatory bodies to be used for International Mobile Telecommunications-Advanced (IMT-Advanced) and all of it or a subset of it may be adopted by 3GPP as licensed bands (e.g., frequency bands) to be used for communication between an eNB and a UE. It should also be noted that in E-UTRA and E-UTRAN overall description, as used herein, a “cell” may be defined as “combination of downlink and optionally uplink resources.” The linking between the carrier frequency of the downlink resources and the carrier frequency of the uplink resources may be indicated in the system information transmitted on the downlink resources.
(35) “Configured cells” are those cells of which the UE is aware and is allowed by an eNB to transmit or receive information. “Configured cell(s)” may be serving cell(s). The UE may receive system information and perform the required measurements on all configured cells. “Configured cell(s)” for a radio connection may include a primary cell and/or no, one, or more secondary cell(s). “Activated cells” are those configured cells on which the UE is transmitting and receiving. That is, activated cells are those cells for which the UE monitors the physical downlink control channel (PDCCH) and in the case of a downlink transmission, those cells for which the UE decodes a physical downlink shared channel (PDSCH). “Deactivated cells” are those configured cells that the UE is not monitoring the transmission PDCCH. It should be noted that a “cell” may be described in terms of differing dimensions. For example, a “cell” may have temporal, spatial (e.g., geographical) and frequency characteristics.
(36) Fifth generation (5G) cellular communications (also referred to as “New Radio,” “New Radio Access Technology” or “NR” by 3GPP) envisions the use of time, frequency and/or space resources to allow for enhanced mobile broadband (eMBB) communication and ultra-reliable low-latency communication (URLLC) services, as well as massive machine type communication (MMTC) like services. To meet a latency target and high reliability, mini-slot-based repetitions with flexible transmission occasions may be supported. Approaches for applying mini-slot-based repetitions are described herein. A new radio (NR) base station may be referred to as a gNB. A gNB may also be more generally referred to as a base station device.
(37) One important objective of 5G is to enable connected industries. 5G connectivity can serve as a catalyst for the next wave of industrial transformation and digitalization, which improve flexibility, enhance productivity and efficiency, reduce maintenance cost, and improve operational safety. Devices in such environments may include, for example, pressure sensors, humidity sensors, thermometers, motion sensors, accelerometers, actuators, etc. It is desirable to connect these sensors and actuators to 5G networks and core. The massive industrial wireless sensor network (IWSN) use cases and requirements include not only URLLC services with very high requirements, but also relatively low-end services with the requirement of small device form factors, and/or being completely wireless with a battery life of several years. The requirements for these services that are higher than low power wide area (LPWA) (e.g., LTE-MTC and/or Narrowband Internet of Things (LTE-M/NB-IOT)) but lower than URLLC and eMBB.
(38) Similar to connected industries, 5G connectivity can serve as a catalyst for the next wave smart city innovations. As an example, the smart city vertical covers data collection and processing to more efficiently monitor and control city resources, and to provide services to city residents. For example, the deployment of surveillance cameras is part of the smart city and may also be used in factories and industries.
(39) Moreover, a wearables use case may include smart watches, rings, eHealth related devices, and medical monitoring devices etc. One characteristic for this use case is that the device is small in size.
(40) These cases above may have some special requirements. The main motivation for the new device type is to lower the device cost and complexity as compared to high-end eMBB and URLLC devices of Rel-15/Rel-16. This is

especially the case for industrial sensors. The requirement for most use cases is that the standard enables a device design with compact form factor. Systems should support all FR1/FR2 bands for FDD and TDD.
(41) This disclosure introduces examples of a UE feature and parameter list with lower end capabilities, relative to Release 16 eMBB and URLLC NR to serve the use cases mentioned above. The use cases, services and/or scenarios described herein may be also be referred to as NR-Light.
(42) Some configurations of the systems and methods described herein teach approaches for NR-Light transmission and/or retransmission management to meet the latency and/or reliability and/or complexity requirements of reduced capability UEs.
(43) Various examples of the systems and methods disclosed herein are now described with reference to the Figures, where like reference numbers may indicate functionally similar elements. The systems and methods as generally described and illustrated in the Figures herein could be arranged and designed in a wide variety of different implementations. Thus, the following more detailed description of several implementations, as represented in the Figures, is not intended to limit scope, as claimed, but is merely representative of the systems and methods.
(44) FIG. **1** is a block diagram illustrating one implementation of one or more base stations (gNBs) **160** and one or more user equipments (UEs) **102** for relaxed uplink processing time. The one or more UEs **102** communicate with one or more gNBs **160** using one or more antennas **122***a-n*. For example, a UE **102** transmits electromagnetic signals to the gNB **160** and receives electromagnetic signals from the gNB **160** using the one or more antennas **122***a-n*. The gNB **160** communicates with the UE **102** using one or more antennas **180***a-n*.
(45) The UE **102** and the gNB **160** may use one or more channels **119**, **121** to communicate with each other. For example, a UE **102** may transmit information or data to the gNB **160** using one or more uplink channels **121**. Examples of uplink channels **121** include a PUCCH (Physical Uplink Control Channel) and a PUSCH (Physical Uplink Shared Channel), PRACH (Physical Random Access Channel), etc. For example, uplink channels **121** (e.g., PUSCH) may be used for transmitting UL data (i.e., Transport Block(s), MAC PDU, and/or UL-SCH (Uplink-Shared Channel)).
(46) In some examples, UL data may include URLLC data. The URLLC data may be UL-SCH data. In some examples, URLLC-PUSCH (i.e., a different Physical Uplink Shared Channel from PUSCH) may be defined for transmitting the URLLC data. For the sake of simple description, the term “PUSCH” may mean any of (1) only PUSCH (e.g., regular PUSCH, non-URLLC-PUSCH, etc.), (2) PUSCH or URLLC-PUSCH, (3) PUSCH and URLLC-PUSCH, or (4) only URLLC-PUSCH (e.g., not regular PUSCH).
(47) Also, for example, uplink channels **121** may be used for transmitting Hybrid Automatic Repeat Request-ACK (HARQ-ACK), Channel State Information (CSI), and/or Scheduling Request (SR). The HARQ-ACK may include information indicating a positive acknowledgment (ACK) or a negative acknowledgment (NACK) for DL data (i.e., Transport Block(s), Medium Access Control Protocol Data Unit (MAC PDU), and/or DL-SCH (Downlink-Shared Channel)).
(48) The CSI may include information indicating a channel quality of downlink. The SR may be used for requesting UL-SCH (Uplink-Shared Channel) resources for new transmission and/or retransmission. For instance, the SR may be used for requesting UL resources for transmitting UL data.
(49) The one or more gNBs **160** may also transmit information or data to the one or more UEs **102** using one or more downlink channels **119**, for instance. Examples of downlink channels **119** include a PDCCH, a PDSCH, etc. Other kinds of channels may be used. The PDCCH may be used for transmitting Downlink Control Information (DCI).
(50) Each of the one or more UEs **102** may include one or more transceivers **118**, one or more demodulators **114**, one or more decoders **108**, one or more encoders **150**, one or more modulators **154**, a data buffer **104** and a UE operations module **124**. For example, one or more reception and/or transmission paths may be implemented in the UE **102**. For convenience, only a single transceiver **118**, decoder **108**, demodulator **114**, encoder **150** and modulator **154** are illustrated in the UE **102**, though multiple parallel elements (e.g., transceivers **118**, decoders **108**, demodulators **114**, encoders **150** and modulators **154**) may be implemented.
(51) The transceiver **118** may include one or more receivers **120** and one or more transmitters **158**. The one or more receivers **120** may receive signals from the gNB **160** using one or more antennas **122***a-n*. For example, the receiver **120** may receive and downconvert signals to produce one or more received signals **116**. The one or more received signals **116** may be provided to a demodulator **114**. The one or more transmitters **158** may transmit signals to the gNB **160** using one or more antennas **122***a-n*. For example, the one or more transmitters **158** may upconvert and transmit one or more modulated signals **156**.
(52) The demodulator **114** may demodulate the one or more received signals **116** to produce one or more demodulated signals **112**. The one or more demodulated signals **112** may be provided to the decoder **108**. The UE **102** may use the decoder **108** to decode signals. The decoder **108** may produce decoded signals **110**, which may include a UE-decoded signal **106** (also referred to as a first UE-decoded signal **106**). For example, the first UE-decoded signal **106** may comprise received payload data, which may be stored in a data buffer **104**. Another signal included in the decoded signals **110** (also referred to as a second UE-decoded signal **110**) may comprise overhead

data and/or control data. For example, the second UE-decoded signal **110** may provide data that may be used by the UE operations module **124** to perform one or more operations.

(53) In general, the UE operations module **124** may enable the UE **102** to communicate with the one or more gNBs **160**. The UE operations module **124** may include a UE scheduling module **126**.

(54) The UE **102** may utilize the UE scheduling module **126** to perform one or more downlink receptions and/or one or more uplink transmissions. The downlink reception(s) may include reception of data, reception of downlink control information, and/or reception of downlink reference signals. The uplink transmissions include transmission of data, transmission of uplink control information, and/or transmission of uplink reference signals.

(55) In a radio communication system, physical channels (e.g., uplink physical channels and/or downlink physical channels) may be defined. The physical channels (e.g., uplink physical channels and/or downlink physical channels) may be used for communicating (e.g., transmitting and/or receiving) information that is delivered from a higher layer.

(56) For example, in uplink, a Physical Random Access Channel (PRACH) may be defined. In some approaches, the PRACH (and/or a random access procedure) may be used for an initial access connection establishment procedure, a handover procedure, a connection re-establishment, a timing adjustment (e.g., a synchronization for an uplink transmission, for UL synchronization) and/or for requesting an uplink shared channel (UL-SCH) resource (e.g., an uplink physical shared channel (PSCH) (e.g., PUSCH) resource).

(57) In some examples, a physical uplink control channel (PUCCH) may be defined. The PUCCH may be used for transmitting uplink control information (UCI). The UCI may include hybrid automatic repeat request-acknowledgement (HARQ-ACK), channel state information (CSI) and/or a scheduling request (SR). The HARQ-ACK may be used for indicating a positive acknowledgement (ACK) or a negative acknowledgment (NACK) for downlink data (e.g., Transport block(s), Medium Access Control Protocol Data Unit (MAC PDU) and/or Downlink Shared Channel (DL-SCH)). The CSI may be used for indicating state of downlink channel (e.g., a downlink signal(s)). The SR may be used for requesting uplink data resources (e.g., Transport block(s), MAC PDU and/or Uplink Shared Channel (UL-SCH)).

(58) The DL-SCH and/or the UL-SCH may be a transport channel or channels used in the MAC layer. One or more transport blocks (TB(s)) and/or a MAC PDU may be defined as a unit(s) of the transport channel used in the MAC layer. The transport block may be defined as a unit of data delivered from the MAC layer to the physical layer. The MAC layer may deliver the transport block to the physical layer (e.g., the MAC layer delivers the data as the transport block to the physical layer). In the physical layer, the transport block may be mapped to one or more codewords.

(59) In downlink, a physical downlink control channel (PDCCH) may be defined. The PDCCH may be used for transmitting downlink control information (DCI). In some examples, more than one DCI format may be defined for DCI transmission on the PDCCH. For instance, fields may be defined in the DCI format(s), and the fields may be mapped to the information bits (e.g., DCI bits).

(60) In some examples, a DCI format 1_0 that is used for scheduling of the PDSCH in the cell may be defined as a DCI format for the downlink. As described herein one or more Radio Network Temporary Identifiers (e.g., the Cell RNTI(s) (C-RNTI(s))), Configured Scheduling RNTI(s) (CS-RNTI(s)), System Information RNTI(s) (SI-RNTI(s)), and/or Random Access RNTI(s) (RA-RNTI(s)) may be used to transmit the DCI format 1_0. In some examples, the DCI format 1_0 may be monitored (e.g., transmitted, mapped) in a Common Search Space (CSS) and/or a UE Specific Search space (USS). In some examples, the DCI format 1_0 may be monitored (e.g., transmitted, mapped) in the CSS only.

(61) For example, a DCI included in the DCI format 1_0 may be a frequency domain resource assignment (e.g., for the PDSCH). Additionally or alternatively, the DCI included in the DCI format 1_0 may be a time domain resource assignment (for a PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_0 may be a modulation and coding scheme (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_0 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 1_0 may be a HARQ process number. Additionally or alternatively, the DCI included in the DCI format 1_0 may be a Transmission Power Control (TPC) command for a scheduled PUCCH. The DCI format 1_0 and/or modified/enhanced DCI format 1_0 may be used for scheduling a PDSCH and/or downlink channel for reduced capability UE(s) and its service(s).

(62) Additionally or alternatively, a DCI format 1_1 that is used for scheduling of the PDSCH in the cell may be defined as a DCI format for the downlink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the DCI format 1_1. Additionally or alternatively, the DCI format 1_1 may be monitored (e.g., transmitted and/or mapped) in the CSS and/or the USS.

(63) For example, the DCI included in the DCI format 1_1 may be a bandwidth part (BWP) indicator (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_1 may be a frequency domain resource assignment (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_1 may be a time domain resource assignment (e.g., for the PDSCH). Additionally or alternatively, the

DCI included in the DCI format 1_1 may be a modulation and coding scheme (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_1 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 11 may be a HARQ process number.

(64) Additionally or alternatively, the DCI included in the DCI format 1_1 may be a TPC command for a scheduled PUCCH. Additionally or alternatively, the DCI included in the DCI format 1_1 may be a CSI request that is used for requesting (e.g., triggering) transmission of the CSI (e.g., CSI reporting (e.g., aperiodic CSI reporting)). Additionally or alternatively, as described below, the DCI included in the DCI format 1_1 may be information (e.g., SPS configuration index) used for indicating an index of a configuration of a DL Semi-Persistent Scheduling (SPS). The DCI format 1_1 and/or modified/enhanced DCI format 1_1 may be used for scheduling a PDSCH and/or downlink channel for reduced capability UE(s) and its service(s).

(65) Additionally or alternatively, a new DCI format (e.g., DCI format 1_2) that is used for scheduling of the PDSCH in the cell may be defined as a DCI format for the downlink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the DCI format 1_2. Additionally or alternatively, the DCI format 1_2 may be monitored (e.g., transmitted and/or mapped) in the CSS and/or the USS.

(66) For example, the DCI included in the DCI format 1_2 may be a BWP indicator (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_2 may be a frequency domain resource assignment (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_2 may be a time domain resource assignment (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_2 may be a modulation and coding scheme (for the PDSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 1_2 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 1_2 may be a HARQ process number. Additionally or alternatively, the DCI included in the DCI format 1_2 may be a TPC command for a scheduled PUCCH. Additionally or alternatively, the DCI included in the DCI format 1_2 may be a CSI request that is used for requesting (e.g., triggering) transmission of the CSI (e.g., CSI reporting (e.g., aperiodic CSI reporting)). Additionally or alternatively, the DCI included in the DCI format 1_2 may be a configurable field(s), e.g., Antenna port(s) [0˜2 bits], Transmission configuration indication [0˜3 bits], Rate matching indicator [0˜2 bits], sounding reference signal (SRS) request [0˜3 bits], PRB bundling size indicator [0˜1 bit], Carrier indicator [0˜3 bits], CSI request [0˜3 bits], ZP CSI-RS triggering [0˜2 bits], Betan offset indicator [0˜2 bits], SRS resource indicator [0˜4 bits], Repetition factor [0˜2 bits], and/or Priority indication [0˜3 bits]. Additionally or alternatively, as described below, the DCI included in the DCI format 1_2 may be information (e.g., SPS configuration index) used for indicating an index of a configuration of a DL Semi-Persistent Scheduling (SPS). The DCI format 1_2 and/or modified/enhanced DCI format 1_2 may be used for scheduling a PDSCH and/or downlink channel for reduced capability UE(s) and its service(s).

(67) Additionally or alternatively, a new DCI format (e.g., DCI format 1_3) that is used for scheduling of the PDSCH in the cell may be defined as a DCI format for the downlink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the new DCI format (e.g., DCI format 1_3). Additionally or alternatively, the DCI format 1_3 may be monitored (e.g., transmitted and/or mapped) in the CSS and/or the USS.

(68) Additionally or alternatively, a DCI format 0_0 that is used for scheduling of the PUSCH in the cell may be defined as a DCI format for the uplink. Additionally or alternatively, the C-RNTI, the CS-RNTI, and/or the Temporary C-RNTI may be used to transmit the DCI format 0_0. Additionally or alternatively, the DCI format 0_0 may be monitored (e.g., transmitted, mapped) in the CSS and/or the USS. In some examples, the DCI format 0_0 may be monitored (e.g., transmitted, mapped) in the CSS only.

(69) For example, the DCI included in the DCI format 0_0 may be a frequency domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_0 may be a time domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_0 may be a modulation and coding scheme (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_0 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 0_0 may be a HARQ process number. Additionally or alternatively, the DCI included in the DCI format 0_0 may be a redundancy version. Additionally or alternatively, the DCI included in the DCI format 0_0 may be a TPC command for a scheduled PUSCH. The DCI format 0_0 and/or modified/enhanced DCI format 0_0 may be used for scheduling a PUSCH and/or uplink channel for reduced capability UE(s) and its service(s). Listing 1 shows an example of DCI format 0_0.

(70) TABLE-US-00001 Listing 1 - Identifier for DCI formats - [1] bit - Frequency domain resource assignment - Time domain resource assignment - X bits as defined in Subclause 6.1.2.1 of [6, TS38.214] - Frequency hopping flag - 1 bit. - Modulation and coding scheme - 5 bits as defined in Subclause 6.1.3 of [6, TS38.214] - New data indicator - 1 bit - Redundancy version - 2 bits as defined in Table 7.3.1.1.1-2 - HARQ process number - 4 bits - TPC command for scheduled PUSCH - [2] bits as defined in Subclause x.x of [5, TS38.213] - UL/SUL indicator - 1 bit for UEs configured with SUL in the cell as defined in Table 7.3.1.1.1-1 and the number of bits for DCI format 1_0 before padding is larger than the number of bits for DCI format 0_0 before padding; 0 bit otherwise.

Additionally or alternatively, a DCI format 0_1 that is used for scheduling of the PUSCH in the cell may be defined as a DCI format for the uplink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the DCI format 0_1. Additionally or alternatively, the DCI format 0_1 may be monitored (e.g., transmitted, mapped) in the CSS and/or the USS.

(71) For example, the DCI included in the DCI format 0_1 may be a BWP indicator (for the PUSCH, for instance). Additionally or alternatively, the DOI included in the DOI format 01 may be a frequency domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 01 may be a time domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_1 may be a modulation and coding scheme (e.g., for the PUSCH). Additionally or alternatively, the DCI included in the DCI format 0_1 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 01 may be a HARQ process number. Additionally or alternatively, the DCI included in the DCI format 0_1 may be a TPC command for a scheduled PUSCH. Additionally or alternatively, the DCI included in the DCI format 0_1 may be a CSI request that is used for requesting the CSI reporting. Additionally or alternatively, as described below, the DCI included in the DCI format 0_1 may be information (e.g., CG configuration index) used for indicating an index of a configuration of a configured grant. The DCI format 0_1 and/or modified/enhanced DCI format 01 may be used for scheduling a PUSCH and/or uplink channel for reduced capability UE(s) and its service(s). Listing 2 shows an example of DCI format 0_1.

(72) TABLE-US-00002 Listing 2 - Carrier indicator - 0 or 3 bits, as defined in Subclause x.x of [5, TS38.213]. - UL/SUL indicator - 0 bit for UEs not configured with SUL in the cell or UEs configured with SUL in the cell but only PUCCH carrier in the cell is configured for PUSCH transmission; 1 bit for UEs configured with SUL in the cell as defined in Table 7.3.1.1.1-1 [TS38.212]. - Identifier for DCI formats - [1] bit - Bandwidth part indicator - 0, 1 or 2 bits as defined in Table 7.3.1.1.2-1 [TS38.212]. The bitwidth for this field is determined according to the higher layer parameter BandwidthPart-Config for the PUSCH. - Frequency domain resource assignment - Time domain resource assignment - 0, 1, 2, 3, or 4 bits as defined in Subclause 6.1.2.1 of [6, TS38.214]. The bitwidth for this field is determined as ┌log.sub.2(I)┐ bits, where I the number of rows in the higher layer parameter [pusch-symbolAllocation]. - VRB-to-PRB mapping - 0 or 1 bit - Frequency hopping flag - 0 or 1 bit - New data indicator - 1 bit - Redundancy version - 2 bits as defined in Table 7.3.1.1.1-2 - HARQ process number - 4 bits - 1.sup.st downlink assignment index - 1 or 2 bits - 2.sup.nd downlink assignment index - 0 or 2 bits - TPC command for scheduled PUSCH - 2 bits as defined in Subclause 7.1.1 of [5, TS38.213] - SRS resource indicator - Precoding information and number of layers - number of bits determined by the following: - Antenna ports - number of bits determined by the following - SRS request - 2 bits as defined by Table 7.3.1.1.2-24 for UEs not configured with SUL in the cell; 3 bits for UEs configured SUL in the cell where the first bit is the non-SUL/SUL indicator as defined in Table 7.3.1.1.1-1 and the second and third bits are defined by Table 7.3.1.1.2-24. - CSI request - 0, 1, 2, 3, 4, 5, or 6 bits determined by higher layer parameter ReportTriggerSize. - CBG transmission information (CBGTI) - 0, 2, 4, 6, or 8 bits determined by higher layer parameter maxCodeBlockGroupsPerTransportBlock for PUSCH. - PTRS-DMRS association - number of bits determined as follows - beta_offset indicator - 0 if the higher layer parameter dynamic in uci-on-PUSCH is not configured; otherwise 2 bits as defined by Table 7.3.1.1.2-27. - DMRS sequence initialization - 0 if the higher layer parameter PUSCH-tp=Enabled or 1 bit if the higher layer parameter PUSCH-tp=Disabled for n.sub.SCID selection defined in Subclause 7.4.1.1.1 of [4, TS38.211].

Additionally or alternatively, a DCI format 0_2 that is used for scheduling of the PUSCH in the cell may be defined as a DCI format for the uplink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the DCI format 0_2. Additionally or alternatively, the DCI format 0_2 may be monitored (e.g., transmitted, mapped) in the CSS and/or the USS.

(73) For example, the DCI included in the DCI format 0_2 may be a BWP indicator (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_2 may be a frequency domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_2 may be a time domain resource assignment (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_2 may be a modulation and coding scheme (for the PUSCH, for instance). Additionally or alternatively, the DCI included in the DCI format 0_2 may be a new data indicator. Additionally or alternatively, the DCI included in the DCI format 0_2 may be a HARQ process number. Additionally or alternatively, the DCI included in the DCI format 0_2 may be a TPC command for a scheduled PUSCH. Additionally or alternatively, the DCI included in the DCI format 0_2 may be a CSI request that is used for requesting the CSI reporting. Additionally or alternatively, the DCI included in the DCI format 0_2 may be a configurable field(s), e.g., Antenna port(s) [0˜2 bits], Transmission configuration indication [0˜3 bits], Rate matching indicator [0˜2 bits], SRS request [0˜3 bits], PRB bundling size indicator [0˜1 bit], Carrier indicator [0˜3 bits], CSI request [0˜3 bits], ZP CSI-RS triggering [0˜2 bits], Betan offset indicator [0˜2 bits], SRS resource indicator [0˜4 bits], Repetition factor [0˜2 bits], and/or Priority indication [0˜3 bits]. Additionally or alternatively, as described below, the DCI included in the DCI format 0_2 may be information (e.g., CG configuration index) used for indicating an index of a configuration of a configured grant. The DCI format 0_2 and/or modified/enhanced DCI format 0_2 may be used for scheduling a PUSCH and/or uplink channel for reduced capability UE(s) and its service(s).

(74) Additionally or alternatively, a new DCI format (e.g., DCI format 0_3) that is used for scheduling of the PUSCH in the cell may be defined as a DCI format for the uplink. Additionally or alternatively, the C-RNTI and/or the CS-RNTI may be used to transmit the DCI format 0_3. Additionally or alternatively, the DCI format 0_3 may be monitored (e.g., transmitted, mapped) in the CSS and/or the USS.
(75) Additionally or alternatively, in a case that the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3 is received (based on the detection of the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3, for example), the UE **102** may perform the PDSCH reception. Additionally or alternatively, in a case that the DCI format 0_0 and/or the DCI format 0_1 and/or the DCI format 0_2 and/or the DCI format 0_3 is received (based on the detection of the DCI format 0_0 and/or the DCI format 0_1 and/or DCI format 0_2 and/or the DCI format 0_3, for example), the UE **102** may perform the PUSCH transmission.
(76) In some examples, as described above, a RNTI(s) (e.g., a Radio Network Temporary Identifier(s)) assigned to the UE **102** may be used for transmission of DCI (e.g., the DCI format(s), DL control channel(s) (e.g., the PDCCH(s))). For instance, the gNB **160** may transmit (by using the RRC message, for example) information used for configuring (e.g., assigning) the RNTI(s) to the UE **102**.
(77) For example, Cyclic Redundancy Check (CRC) parity bits (which may be referred to simply as CRC), which are generated based on DCI, may be attached to DCI, and, after attachment, the CRC parity bits may be scrambled by the RNTI(s). The UE **102** may attempt to decode (e.g., blind decode, monitor, detect) DCI to which the CRC parity bits scrambled by the RNTI(s) are attached. For example, the UE **102** may detect a DL control channel (e.g., the PDCCH, the DCI, the DCI format(s)) based on the blind decoding. For instance, the UE **102** may decode the DL control channel(s) with the CRC scrambled by the RNTI(s). In other words, the UE **102** may monitor the DL control channel(s) with the RNTI(s). For example, the UE **102** may detect the DCI format(s) with the RNTI(s).
(78) In some examples, the RNTI(s) may include the C-RNTI(s) (Cell-RNTI(s)), the CS-RNTI(s) (Configured Scheduling C-RNTI(s)), the SI-RNTI(s) (System Information RNTI(s)), the RA-RNTI(s) (Random Access-RNTI(s)), and/or the Temporary C-RNTI(s). For example, the C-RNTI(s) may be a unique identification used for identifying an RRC connection and/or scheduling. Additionally or alternatively, the CS-RNTI(s) may be a unique identification used for scheduling of transmission based on a configured grant. Additionally or alternatively, the SI-RNTI may be used for identifying system information (SI) (e.g., an SI message) mapped on the BCCH and dynamically carried on DL-SCH. Additionally or alternatively, the SI-RNTI may be used for broadcasting of SI. Additionally or alternatively, the RA-RNTI may be an identification used for the random access procedure (e.g., Msg.2 transmission). Additionally or alternatively, the Temporary C-RNTI may be used for the random access procedure (e.g., scheduling of Msg.3 (re)transmission (e.g., Msg.3 PUSCH (re)transmission)).
(79) Additionally or alternatively, a new RNTI (e.g., L-RNTI) may be introduced for reduced capability UE(s) and its service(s). For example, in a case that the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3 with CRC scrambled by L-RNTI is received (based on the detection of the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3, for example), the UE **102** may perform the PDSCH reception for NR light transmission service(s). Additionally or alternatively, in a case that the DCI format 0_0 and/or the DCI format 0_1 and/or the DCI format 0_2 and/or the DCI format 0_3 with CRC scrambled by L-RNTI is received (based on the detection of the DCI format 0_0 and/or the DCI format 0_1 and/or DCI format 0_2 and/or the DCI format 0_3, for example), the UE **102** may perform the PUSCH transmission for NR light transmission service(s).
(80) Additionally or alternatively, separate RNTIs may be introduced for UL and DL. For example, a new RNTI (e.g., L-UL-RNTI) may be introduced for reduced capability UE(s) and its UL transmission service(s) while a new RNTI (e.g., L-DL-RNTI) may be introduced for reduced capability UE(s) and its DL transmission service(s). In a case that the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3 with CRC scrambled by L-DL-RNTI is received (based on the detection of the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3, for example), the UE **102** may perform the PDSCH reception for NR light transmission service(s). Additionally or alternatively, in a case that the DCI format 0_0 and/or the DCI format 0_1 and/or the DCI format 0_2 and/or the DCI format 0_3 with CRC scrambled by L-UP-RNTI is received (based on the detection of the DCI format 0_0 and/or the DCI format 0_1 and/or DCI format 0_2 and/or the DCI format 0_3, for example), the UE **102** may perform the PUSCH transmission for NR light transmission service(s).
(81) Additionally or alternatively, a physical downlink shared channel (PDSCH) and a physical uplink shared channel (PUSCH) may be defined. For example, in a case that the PDSCH (e.g., the PDSCH resource) is scheduled by using the DCI format(s), the UE **102** may receive the downlink data, on the scheduled PDSCH (e.g., the PDSCH resource). Additionally or alternatively, in a case that the PUSCH (e.g., the PUSCH resource) is scheduled by using the DCI format(s), the UE **102** transmits the uplink data on the scheduled PUSCH (e.g., the PUSCH resource). For example, the PDSCH may be used to transmit the downlink data (e.g., DL-SCH(s), a downlink transport block(s)). Additionally or alternatively, the PUSCH may be used to transmit the uplink data (e.g., UL-SCH(s), an uplink

transport block(s)).
(82) In some examples, the PDSCH and/or the PUSCH may be used to transmit information of a higher layer (e.g., a radio resource control (RRC)) layer, and/or a MAC layer). For example, the PDSCH (from the gNB **160** to the UE **102**, for instance) and/or the PUSCH (from the UE **102** to the gNB **160**, for instance) may be used to transmit an RRC message (e.g., an RRC signal). Additionally or alternatively, the PDSCH (from the gNB **160** to the UE **102**, for instance) and/or the PUSCH (from the UE **102** to the gNB **160**, for instance) may be used to transmit a MAC control element (a MAC CE). In some examples, the RRC message and/or the MAC CE may be referred to as a higher layer signal.
(83) In some approaches, a physical broadcast channel (PBCH) may be defined. For example, the PBCH may be used for broadcasting the master information block (MIB).
(84) In some examples, system information may be divided into the MIB and a number of system information block(s) (SIB(s)). For example, the MIB may be used for carrying minimum system information. Additionally or alternatively, the SIB(s) may be used for carrying system information messages.
(85) In some approaches, in downlink, a Synchronization Signal (SS) may be defined. The SS may be used for acquiring time and/or frequency synchronization with a cell. Additionally or alternatively, the SS may be used for detecting a physical layer cell ID of the cell.
(86) In the radio communication for uplink, UL reference signal(s) (RS(s)) may be used as uplink physical signal(s). Additionally or alternatively, in the radio communication for downlink, DL RS(s) may be used as downlink physical signal(s). In some examples, the uplink physical signal(s) and/or the downlink physical signal(s) may not be used to transmit information that is provided from the higher layer, but is used by a physical layer.
(87) In some examples, the downlink physical channel(s) and/or the downlink physical signal(s) described herein may be assumed to be included in a downlink signal (e.g., a DL signal(s)) in some implementations for the sake of simple descriptions. Additionally or alternatively, the uplink physical channel(s) and/or the uplink physical signal(s) described herein may be assumed to be included in an uplink signal (i.e. an UL signal(s)) in some implementations for the sake of simple descriptions.
(88) The details of new DCI formats (e.g., DCI format 0_3, DCI format 1_3) are described herein.
(89) For reduced capability UE(s) and its service(s), the current DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2) may not be supportive and/or suitable. Some information may be necessary to be updated/modified in DCI (e.g., antenna port(s), transmission configuration indication, rate matching indicator, SRS request, PRB bundling size indicator, carrier indicator, CSI request, ZP CSI-RS triggering, betan offset indicator, SRS resource indicator, repetition factor, priority indication, and so on). The potential UE complexity reduction features may include reduced number of UE RX/TX antennas, UE Bandwidth reduction (e.g., Rel-15 SSB bandwidth should be reused and L1 changes minimized), relaxed UE processing time, Half-Duplex-FDD, relaxed UE processing capability, reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits. In this case, a new DCI format and/or current DCI format with modifications and/or enhancements may be introduced.
(90) In an implementation, a new DCI format (e.g., DCI format 0_3, specifications may use a different name) may be introduced. DCI format 0_3 may be used for the scheduling of PUSCH in one cell. The following information may be transmitted by means of the DCI format 0_3.
(91) DCI format 0_3 may include an identifier for DCI formats. The value of this field may be set to a predefined and/or defaulted value (e.g., 0 or 1), indicating a new/different DCI format (comparing to DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) for reduced capability UE(s) and its service(s).
(92) DCI format 0_3 may include an identifier for UL/DL DCI formats. The value of this field may be set to a predefined and/or defaulted value (e.g., 0 or 1), indicating an UL DCI format.
(93) DCI format 0_3 may include modulation and coding scheme (MCS) field. The bitwidth of the MCS filed may be 5 bits or a reduced size (e.g., 1, 2, 3, 4 bits). The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured MCS table (e.g., higher layer parameter mcs-Table). Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) configured for other DCI format(s) (e.g., DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. Existing MCS tables for current DCI formats (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2) may be reused/provided for DCI format 0_3, e.g., qam256 table, qam64 table or qam64LowSE table. A new MCS table may be configured/provided for DCI format 0_3 separately, e.g., a new MCS table with 16 (or less than 16) rows. In yet another implementation, a truncated existing MCS table(s) may be used/configured/provided for DCI format 0_3. Namely, some of rows in the existing MCS table(s) for current DCI formats (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2) may be configured/provided for DCI format 0_3.
(94) DCI format 0_3 may include antenna ports. The number of bits in this bit field may be 0-2 bits. The number of

bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured waveform (e.g., whether transform precoder is enabled or not). The number of bits in this bit field may be determined by DMRS type, rank, codebook and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) configured for other DCI format(s) (e.g., DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field may be 0 bit if a higher layer parameter (e.g., AntennaPorts-FieldPresence-ForDCIFormat0_3) is not configured. If the higher layer parameter (e.g., AntennaPorts-FieldPresence-ForDCIFormat0_3) is configured, the field size may be a fixed value (e.g., 1, 2) defined in the spec, or determined by other higher layer parameters, e.g., transform precoder enabler, DMRS type, max length, codebook, mapping type (e.g., dmrs-UplinkForPUSCH-MappingTypeA-ForDCIFormat0_3 and/or dmrs-UplinkForPUSCH-MappingTypeB-ForDCIFormat0_3).

(95) DCI format 0_3 may include a transmission configuration indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured number of multiple transmission configurations. For example, if multiple configurations are not enabled, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of transmission configuration is 8, the number of bits in this field may be 3. If multiple transmission configurations are enabled and/or configured, only DCI format 0_3 may be used to activate and/or deactivate corresponding configured grant(s).

(96) DCI format 0_3 may include an SRS request. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured carrier (e.g., whether SUL is configured or not). The number of bits in this bit field may be determined by a configured and/or predefined table and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) (e.g., DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, For example, the field may be 0 bit if a higher layer parameter (e.g., SRSRequest-ForDCIFormat0_3) is not configured. If the higher layer parameter (e.g., SRSRequest-ForDCIFormat0_3) is configured, the field size may be provided/determined by the higher layer parameter (e.g., SRSRequest-ForDCIFormat0_3). The field size may be a fixed value (e.g., 1, 2) defined in the spec. The field size may also be determined by other higher layer parameters, e.g., supplement uplink (e.g., supplementaryUplink in ServingCellConfig).

(97) DCI format 0_3 may include a carrier indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured number of carriers. For example, if multiple carriers are not enabled and/or configured, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of carriers is larger than 4, the number of bits in this field may be 3. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) (e.g., DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field size may be a value (e.g., 0, 1, 2 or 3 bits) determined by higher layer parameter (e.g., CarrierIndicatorSize-ForDCIFormat0_3).

(98) DCI format 0_3 may include a CSI request. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by CSI configuration. The number of bits in this bit field may be determined by a configured and/or predefined table, and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) (e.g., DCI format 0_0 and/or DCI format 0_1 and/or DCI format 0_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field size may be value (e.g., 0, 1, 2, 3, 4, 5, or 6 bits) determined by higher layer parameter (reportTriggerSize-ForDCIFormat0_3).

(99) DCI format 0_3 may include a beta_offset indicator. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by beta_offset configuration type (e.g., whether beta_offset is semi-static or dynamic). The number of bits in this bit field may be determined by the configured set of beta_offsets. The number of bits in this bit field may be determined by a configured and/or predefined table, and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field size may be determined by configured betan offset (e.g., semi-static or dynamic) and or configured number of offset indexes. The field size may be 0 bit if the higher layer parameter betaOffsets=semiStatic; otherwise 1 bit if 2 offset indexes are configured by higher layer parameter (e.g., dynamic-ForDCIFormat0_3) and 2 bits if 4 offset indexes are configured by higher layer parameter (e.g., dynamic-ForDCIFormat0_3).
(100) DCI format 0_3 may include an SRS resource indicator. The number of bits in this bit field may be 0-4 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of configured SRS resources in the SRS resource set. The number of bits in this bit field may be determined by the maximum number of supported layers for the PUSCH, codebook and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field size may be determined by the number of configured SRS resources in the SRS resource set configured by higher layer parameter (e.g., srs-ResourceSetToAddModList-ForDCIFormat0_3), codebook (e.g., higher layer parameter usage of value ‘codeBook’ or ‘nonCodeBook’), number of layers (e.g., maxMIMOLayers-ForDCIFormat0_3), SRS resource set (e.g., srs-ResourceSetToAddModList-ForDCIFormat0_3).
(101) DCI format 0_3 may include a repetition factor. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured and/or predefined set of repetition factors. For example, if dynamic indication of repetition factor is not enabled, configured and/or supported, the number of bits in this field is 0 or this bit field is absent in DCI. If dynamic indication of repetition factor is enabled, configured and/or supported, and/or the number of repetition factors in the configured and/or predefined set is 4 (e.g., {1, 2, 4, 8}), the number of bits in this field may be 2. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately.
(102) DCI format 0_3 may include a priority indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured and/or predefined set of priority levels and or the number of configured and/or predefined priority levels. For example, if PUSCH prioritization is not enabled, configured and/or supported, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of configured and/or predefined PUSCH priority levels is 4 (e.g., {0, 1, 2, 3}), the number of bits in this field may be 2. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 0_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, the field size may be 0 bit if higher layer parameter (e.g., PriorityIndicator-ForDCIFormat0_3) is not configured; otherwise the field size may be a value (e.g., 1 bit) provided by the higher layer parameter (e.g., PriorityIndicator-ForDCIFormat0_3).
(103) DCI format 0_3 may include a frequency domain resource assignment. The number of bits in this bit field may be 0-6 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of RBGs, resource allocation type, granularity by high layer (e.g., RRC configuration). Any of the high layer parameters (e.g.,

configured number of RBGs, resource allocation type, granularity) used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) (e.g., number of RBGs, resource allocation type, granularity) configured for other DCI format(s) field size determination may be also applied to the corresponding bit field for DCI format 0_3, or parameter(s) and/or table(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, The bitwidth for this field is determined by higher layer parameters number of RBGs, resource allocation type, granularity (e.g., ResourceAllocationType1-granularity-ForDCIFormat0_3).

(104) DCI format 0_3 may include a time domain resource assignment. The number of bits in this bit field may be 0-6 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of entries in the time domain resource assignment table configured by high layer (e.g., RRC configuration) or a defaulted time domain resource assignment table. Any of the high layer parameters (e.g., configured time domain resource assignment table, defaulted and/or predefined time domain resource assignment table) used to determine the number of bits in this field may be commonly configured for DCI format 0_3 and other DCI formats, or separately configured for DCI format 0_3. In other words, parameter(s) (e.g., time domain resource assignment table configured by high layer) configured for other DCI format(s) field size determination may be also applied to the corresponding bit field for DCI format 0_3, or parameter(s) and/or table(s) used to determine the number of bits in the corresponding bit field for DCI format 0_3 may be configured separately. For example, The bitwidth for this field is determined as ┌log.sub.2 (I)┐ bits, where I is the number of entries in the dedicated higher layer parameter (e.g., PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3) if the dedicated higher layer parameter is configured, or I is the number of entries in the common higher layer parameter (e.g., PUSCH-TimeDomainResourceAllocationList) if the common higher layer parameter (e.g., PUSCH-TimeDomainResourceAllocationList) is configured and the dedicated higher layer parameter (e.g., PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3) is not configured; otherwise I is the number of entries in the default table.

(105) In yet another implementation, a new DCI format may not be introduced, but modifications and/or enhancements of current DCI format(s) may be used to schedule PUSCH for reduced capability UE(s) and its service(s). Reinterpretation of field(s) in current DCI format (e.g., DCI format 0_0 or DCI format 0_1, or DCI format 0_2) may be applied to provide necessary information to schedule PUSCH for reduced capability UE(s) and its service(s).

(106) Bit(s) or part of bits of some bit fields (e.g., frequency domain resource assignment, time domain resource assignment, frequency hopping flag, modulation and coding scheme, new data indicator, redundancy version, HARQ process number, TPC command for scheduled PUSCH, UL/UL indicator, etc.) in DCI format 0_0 (or DCI format 0_1 or DCI format 0_2) may be reinterpreted as a different bit field(s) (e.g., antenna port(s), transmission configuration indication, SRS request, carrier indicator, CSI request, betan offset indicator, SRS resource indicator, repetition factor, priority indication, etc.) if the reinterpretation is RRC configured, indicated explicitly or implicitly.

(107) Existing DCI formats (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2) may be used to schedule PUSCH for reduced capability UE(s) and its service(s). The field size of each field in the existing DCI format(s) may be determined by separate RRC parameter dedicated for NR light as mentioned above (DCI field determination for DCI format 0_3). The DCI format 0_3 described above may be renamed from the existing DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2) or alias of the existing DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2).

(108) For reduced capability UE(s) and its service(s), the current DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2) may not be supportive/suitable. Some information may be necessary to be updated/modified in DCI (e.g., antenna port(s), transmission configuration indication, rate matching indicator, SRS request, PRB bundling size indicator, carrier indicator, CSI request, ZP CSI-RS triggering, betan offset indicator, SRS resource indicator, repetition factor, priority indication, and so on). The potential UE complexity reduction features may include reduced number of UE RX/TX antennas, UE Bandwidth reduction (e.g., Rel-15 SSB bandwidth should be reused and L1 changes minimized), relaxed UE processing time, Half-Duplex-FDD, relaxed UE processing capability, reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits. In this case, a new DCI format and/or current DCI format with modifications and/or enhancements may be introduced for downlink.

(109) For downlink, to support reduced capability UE(s) and its service(s), similarly, a new DCI format and/or current DCI format with modifications and/or enhancements may be also introduced. The DL DCI may use the same and/or a common structure and/or implementation as the UL DCI mentioned above, or the DL DCI may be implemented separately.

(110) In an implementation, a new DCI format (e.g., DCI format 1_3, specifications may use a different name) may be introduced. DCI format 1_3 may be used for the scheduling of PDSCH in one cell. The following information may be transmitted by means of the DCI format 1_3.

(111) DCI format 1_3 may include an identifier for DCI formats. The value of this field may be set to a predefined

and/or defaulted value (e.g., 0 or 1), indicating a new/different DCI format (comparing to DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2) for reduced capability UE(s) and its service(s).

(112) DCI format 1_3 may include an identifier for UL/DL DCI formats. The value of this field may be set to a predefined and/or defaulted value (e.g., 0 or 1), indicating an DL DCI format.

(113) DCI format 1_3 may include modulation and coding scheme (MCS) field. The bitwidth of the MCS filed may be 5 bits or a reduced size (e.g., 1, 2, 3, 4 bits). The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured MCS table (e.g., higher layer parameter mcs-Table). Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) configured for other DCI format(s) (e.g., DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. Existing MCS tables for current DCI formats (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2) may be reused/provided for DCI format 1_3, e.g., qam256 table, qam64 table or qam64LowSE table. A new MCS table may be configured/provided for DCI format 1_3 separately, e.g., a new MCS table with 16 (or less than 16) rows. In yet another implementation, a truncated existing MCS table(s) may be used/configured/provided for DCI format 1_3. Namely, some of rows in the existing MCS table(s) for current DCI formats (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2) may be configured/provided for DCI format 1_3.

(114) DCI format 1_3 may include antenna ports. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured waveform (e.g., whether transform precoder is enabled or not). The number of bits in this bit field may be determined by DMRS type, rank, codebook and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) configured for other DCI format(s) (e.g., DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the field may be 0 bit if a higher layer parameter (e.g., AntennaPorts-FieldPresence-ForDCIFormat1_3) is not configured. If the higher layer parameter (e.g., AntennaPorts-FieldPresence-ForDCIFormat1_3) is configured, the field size may be a fixed value (e.g., 1, 2) defined in the spec, or determined by other higher layer parameters, e.g., transform precoder enabler, DMRS type, max length, codebook, mapping type (e.g., dmrs-DownlinkForPDSCH-MappingTypeA-ForDCIFormat1_3 and/or dmrs-DownlinkForPDSCH-MappingTypeB-ForDCIFormat1_3).

(115) DCI format 1_3 may include a transmission configuration indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured number of multiple transmission configurations. For example, if multiple configurations of DL semi-persistent scheduling (SPS) are not enabled, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of transmission configuration is 8, the number of bits in this field may be 3. If multiple transmission configurations are enabled and/or configured, only DCI format 1_3 may be used to activate and/or deactivate corresponding SPS.

(116) DCI format 1_3 may include an SRS request. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured carrier (e.g., whether SUL is configured or not). The number of bits in this bit field may be determined by a configured and/or predefined table and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) (e.g., DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, For example, the field may be 0 bit if a higher layer parameter (e.g., SRSRequest-ForDCIFormat1_3) is not configured. If the higher layer parameter (e.g., SRSRequest-ForDCIFormat1_3) is configured, the field size may be provided/determined by the higher layer parameter (e.g., SRSRequest-ForDCIFormat1_3). The field size may be a fixed value (e.g., 1, 2) defined in the spec. The field size may also be determined by other higher layer parameters, e.g., supplement uplink (e.g., supplementaryUplink in ServingCellConfig).

(117) DCI format 1_3 may include a carrier indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured number of carriers. For example,

if multiple carriers are not enabled and/or configured, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of carriers is larger than 4, the number of bits in this field may be 3. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) and/or table(s) configured for other DCI format(s) (e.g., DCI format 1_0 and/or DCI format 1_1 and/or DCI format 1_2) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the field size may be a value (e.g., 0, 1, 2 or 3 bits) determined by higher layer parameter (e.g., CarrierIndicatorSize-ForDCIFormat1_3).

(118) DCI format 1_3 may include a rate matching indicator. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured rate matching pattern group(s) and/or any related high layer parameters. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the field size may be 0, 1, or 2 bits according to higher layer parameters rateMatchPatternGroup1-ForDCIFormat1_3 and rateMatchPatternGroup2-ForDCIFormat1_3, where the MSB is used to indicate rateMatchPatternGroup1-ForDCIFormat1_3 and the LSB is used to indicate rateMatchPatternGroup2-ForDCIFormat1_3 when there are two groups.

(119) DCI format 1_3 may include a PRB bundling size indicator. The number of bits in this bit field may be 0-1 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by configured PRB bundling type (e.g., whether PRB bundling is configured or not, whether PRB bundling type is configured as static or dynamic). If PRB bundling is not configured or is set as static, the number of bits in this field is 0 or this bit field is absent in DCI. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the field size may be 0 bit if the higher layer parameter PRB bundling type (e.g., prbBundlingType-ForDCIFormat1_3) is not configured or is set to 'static', or 1 bit if the higher layer parameter PRB bundling type (e.g., prbBundlingType-ForDCIFormat1_3) is set to 'dynamic'.

(120) DCI format 1_3 may include ZP CSI-RS triggering. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of ZP CSI-RS resource sets configured in the higher layer parameter and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the bitwidth for this field is determined as $\lceil \log_2 (n_{ZP}+1) \rceil$ bits, where n_{ZP} is the number of aperiodic ZP CSI-RS resource sets configured by higher layer parameter aperiodic-ZP-CSI-RS-ResourceSetsToAddModList-ForDCIFormat1_3.

(121) DCI format 1_3 may include a repetition factor. The number of bits in this bit field may be 0-2 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by a configured and/or predefined set of repetition factors. For example, if dynamic indication of repetition factor is not enabled, configured and/or supported, the number of bits in this field is 0 or this bit field is absent in DCI. If dynamic indication of repetition factor is enabled, configured and/or supported, and/or the number of repetition factors in the configured and/or predefined set is 4 (e.g., {1, 2, 4, 8}), the number of bits in this field may be 2. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately.

(122) DCI format 1_3 may include a priority indication. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer

parameter). The number of bits in this bit field may be determined by a configured and/or predefined set of priority levels and or the number of configured and/or predefined priority levels. For example, if PDSCH prioritization is not enabled, configured and/or supported, the number of bits in this field is 0 or this bit field is absent in DCI. If the number of configured and/or predefined PDSCH priority levels is 4 (e.g., {0, 1, 2, 3}), the number of bits in this field may be 2. Any of the high layer parameters, sets and/or tables used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s), table(s) and/or set(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s), table(s) and/or set(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the field size may be 0 bit if higher layer parameter (e.g., PriorityIndicator-ForDCIFormat1_3) is not configured; otherwise the field size may be a value (e.g., 1 bit) provided by the higher layer parameter (e.g., PriorityIndicator-ForDCIFormat1_3).

(123) DCI format 1_3 may include a frequency domain resource assignment. The number of bits in this bit field may be 0-6 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of RBGs, resource allocation type, granularity by high layer (e.g., RRC configuration). Any of the high layer parameters (e.g., configured number of RBGs, resource allocation type, granularity) used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) (e.g., number of RBGs, resource allocation type, granularity) configured for other DCI format(s) field size determination may be also applied to the corresponding bit field for DCI format 1_3, or parameter(s) and/or table(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, The bitwidth for this field is determined by higher layer parameters number of RBGs, resource allocation type, granularity (e.g., ResourceAllocationType1-granularity-ForDCIFormat1_3). DCI format 1_3 may include a time domain resource assignment. The number of bits in this bit field may be 0-6 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of entries in the time domain resource assignment table configured by high layer (e.g., RRC configuration) or a defaulted time domain resource assignment table. Any of the high layer parameters (e.g., configured time domain resource assignment table, defaulted and/or predefined time domain resource assignment table) used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) (e.g., time domain resource assignment table configured by high layer) configured for other DCI format(s) field size determination may be also applied to the corresponding bit field for DCI format 1_3, or parameter(s) and/or table(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, The bitwidth for this field is determined as ┌log.sub.2 (I)┐ bits, where I is the number of entries in the dedicated higher layer parameter (e.g., PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3) if the dedicated higher layer parameter is configured, or I is the number of entries in the common higher layer parameter (e.g., PDSCH-TimeDomainResourceAllocationList) if the common higher layer parameter (e.g., PDSCH-TimeDomainResourceAllocationList) is configured and the dedicated higher layer parameter (e.g., PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3) is not configured; otherwise I is the number of entries in the default table. DCI format 1_3 may include PDSCH-to-HARQ_feedback timing indicator. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). The number of bits in this bit field may be determined by the number of K1 (i.e., delay between PDSCH reception and HARQ-ACK feedback) values configured in the higher layer parameter and/or any other related high layer parameters. Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the bitwidth for this field is determined as ┌log.sub.2(I)┐ bits, where I is the number of entries in the higher layer parameter dl-DataToUL-ACK-ForDCIFormat1_3.

(124) DCI format 1_3 may include PUCCH resource indicator. The number of bits in this bit field may be 0-3 bits. The number of bits in this bit field may be determined by higher layer (e.g., RRC configuration, an explicit high layer parameter). Any of the high layer parameters used to determine the number of bits in this field may be commonly configured for DCI format 1_3 and other DCI formats, or separately configured for DCI format 1_3. In other words, parameter(s) configured for other DCI format(s) field size determination may be also used to determine the number of bits in the corresponding bit field for DCI format 1_3, or parameter(s) used to determine the number of bits in the corresponding bit field for DCI format 1_3 may be configured separately. For example, the bitwidth for this field may be 0 or 1 or 2 or 3 bits determined by higher layer parameter Numberofbits-

forPUCCHresourceindicator-ForDCIFormat1_3.

(125) In yet another implementation, a new DL DCI format may not be introduced, but modifications and/or enhancements of current DCI format(s) may be needed to schedule PDSCH for reduced capability UE(s) and its service(s). Reinterpretation of field(s) in current DCI format (e.g., DCI format 1_0 or DCI format 1_1 or DCI format 1_2) may be applied to provide necessary information to schedule PDSCH for reduced capability UE(s) and its service(s).

(126) Bit(s) or part of bits of some bit fields (e.g., frequency domain resource assignment, time domain resource assignment, VRB-to-PRB mapping, modulation and coding scheme, new data indicator, redundancy version, HARQ process number, downlink assignment index, TPC command for scheduled PUCCH, PUCCH resource indicator, PDSCH-to-HARQ_feedback timing indicator, etc.) in DCI format 1_0 (or DCI format 1_1 or DCI format 1_2) may be reinterpreted as a different bit field(s) (e.g., antenna port(s), transmission configuration indication, PRB bundling size indicator, carrier indicator, rate matching indicator, ZP CSI-RS trigger, SRS request, repetition factor, priority indication, etc.) if the reinterpretation is RRC configured, indicated explicitly or implicitly.

(127) Existing DCI formats (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2) may be used to schedule PUSCH for reduced capability UE(s) and its service(s). The field size of each field in the existing DCI format(s) may be determined by separate RRC parameter dedicated for NR light as mentioned above (DCI field determination for DCI format 1_3). The DCI format 1_3 described above may be renamed from the existing DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2) or alias of the existing DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2).

(128) The UE scheduling module **126** may perform operations for mini-slot-based repetitions. In new radio (NR), a UE **102** may support multiple types of UL transmissions (PUSCH transmissions). The UL transmissions may include grant-based UL transmissions (e.g., UL transmissions with grant, dynamic grants, PUSCH transmissions with grant, PUSCH transmission scheduled by DCI (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2, DCI format 0_3)) and grant-free UL transmissions (e.g., UL transmissions without grant, configured grants, PUSCH transmissions with configured grant).

(129) For grant-based transmission, PUSCH transmission is scheduled by DCI (e.g., the DCI format 0_0, the DCI format 0_1, the DCI format 0_2, and the DCI format 0_3 shown above). The PUSCH may be assigned (e.g., scheduled) by a DCI format 0_0/0_1/0_2/0_3 with CRC scrambled by C-RNTI, MCS-C-RNTI, a new-RNTI (e.g., a L-RNTI), TC-RNTI, or SP-CSI-RNTI. Some UE-specific PUSCH parameters may be configured by RRC (i.e., using the RRC message (the RRC signaling)). An example for RRC configuration is shown in Listing 3. For example, pusch-AggregationFactor in PUSCH-Config indicates number of repetitions for data. When the UE **102** is configured with pusch-AggregationFactor>1, the same symbol allocation may be applied across the pusch-AggregationFactor consecutive slots and the PUSCH may be limited to a single transmission layer. The UE **102** may repeat the transport block (TB) across the pusch-AggregationFactor consecutive slots applying the same symbol allocation in each slot. If the UE procedure for determining the slot configuration, determines symbols of a slot allocated for PUSCH as downlink symbols, the transmission on that slot may be omitted for multi-slot PUSCH transmission.

(130) For the PUSCH retransmission scheduled by a PDCCH with CRC scrambled by CS-RNTI with NDI=1, the parameters in pusch-Config may be applied for the PUSCH transmission except for p0-NominalWithoutGrant, p0-PUSCH-Alpha, powerControlLoopToUse, pathlossReferenceIndex, mcs-Table, mcs-TableTransformPrecoder and transformPrecoder, which may be provided in configuredGrantConfig.

(131) For the PUSCH retransmission scheduled by a PDCCH with CRC scrambled by CS-RNTI with new data indicator (NDI) equal to 1 (i.e., NDI=1), if the UE **102** is configured with pusch-AggregationFactor, the same symbol allocation may be applied across the pusch-AggregationFactor consecutive slots and the PUSCH may be limited to a single transmission layer. The UE **102** may repeat the TB across the puschAggregationFactor consecutive slots applying the same symbol allocation in each slot.

(132) TABLE-US-00003 Listing 3 -- ASN1START -- TAG-PUSCH-CONFIG-START PUSCH-Config : := SEQUENCE { dataScramblingIdentityPUSCH INTEGER (0..1023) OPTIONAL, -- Need M txConfig ENUMERATED {codebook, nonCodebook} OPTIONAL, -- Need S dmrs-UplinkForPUSCH-MappingTypeA SetupRelease { DMRS-UplinkConfig } OPTIONAL, -- Need M dmrs-UplinkForPUSCH-MappingTypeB SetupRelease { DMRS-UplinkConfig } OPTIONAL, -- Need M pusch-PowerControl PUSCH-PowerControl OPTIONAL, -- Need M frequencyHopping ENUMERATED {mode1, mode2} OPTIONAL, -- Need S frequencyHoppingOffsetLists SEQUENCE (SIZE (1..4)) OF INTEGER (1.. maxNrofPhysicalResourceBlocks-1) OPTIONAL, -- Need M resourceAllocation ENUMERATED { resourceAllocationType0, resourceAllocationType1, dynamicSwitch}, pusch-TimeDomainAllocationList SetupRelease { PUSCH-TimeDomainResourceAllocationList } OPTIONAL, -- Need M pusch-AggregationFactor ENUMERATED { n2, n4, n8 } OPTIONAL, -- Need S mcs-Table ENUMERATED {qam256, spare1} OPTIONAL,

-- Need S mcs-TableTransformPrecoder ENUMERATED {qam256, spare1} OPTIONAL, -- Need S transformPrecoder ENUMERATED {enabled, disabled} OPTIONAL, -- Need S codebookSubset ENUMERATED { fullyAndPartialAndNonCoherent, partialAndNonCoherent, nonCoherent} OPTIONAL, -- Cond codebookBased maxRank INTEGER (1..4) OPTIONAL, -- Cond codebookBased rbg-Size ENUMERATED { config2} OPTIONAL, -- Need S uci-OnPUSCH SetupRelease { UCI-OnPUSCH} OPTIONAL, -- Need M tp-pi2BPSK ENUMERATED {enabled} OPTIONAL, -- Need S . . . } UCI-OnPUSCH : := SEQUENCE { betaOffsets CHOICE { dynamic SEQUENCE (SIZE (4)) OF BetaOffsets, semiStatic BetaOffsets } OPTIONAL, -- Need M scaling ENUMERATED { f0p5, f0p65, f0p8, f1 } } -- TAG-PUSCH-CONFIG-STOP -- ASN1STOP

In some examples, the UE scheduling module **126** may perform time-domain resource allocation. Approaches to determine time-domain resource allocation (TDRA) for one or more (e.g., all) channels are described herein.

(133) As mentioned above, a field named Time domain resource assignment may be used to indicate time-domain resource allocation of a slot(s) and/or a mini-slot(s) and/or a symbol(s). It should be noted that this field may have a different name in some specifications relating to, for example, resource allocation (RA). For example, the Time domain resource assignment field value m may provide (e.g., be used for indicating) a row index m+1 to an allocation table. The determination of the used resource allocation table may be as defined based on some rules. The indexed row may define a value(s) of the slot offset(s) and/or the mini-slot offset(s) and/or the symbol offset(s) (e.g., K.sub.0 for downlink, and/or K.sub.2 for uplink). The indexed row may define the start and length indicator (SLIV), or may directly indicate the start symbol S and the allocation length L. The indexed row may define a value(s) of the PDSCH mapping and/or the PUSCH mapping type to be assumed in the PDSCH/PUSCH reception. The indexed row may define a value(s) of the number of repetitions to be assumed in the PDSCH/PUSCH reception. For example, the Time domain resource assignment field may be used to indicate a time domain relation between the PDCCH and the PDSCH (e.g., K.sub.0 and/or a position(s) of the slot(s), the mini-slot(s), and/or the symbols(s) for the PDSCH scheduled by using the corresponding PDCCH), or a time domain relation between the PDCCH and the PUSCH (e.g., K.sub.2 and/or a position(s) of the slot(s), the mini-slot(s), and/or the symbols(s) for the PUSCH scheduled by using the corresponding PDCCH), or a time domain relation between a reference point (e.g., period boundary, slot boundary, subframe boundary, system frame number (SFN)=0, the starting symbol of the PDCCH monitoring occasion in which the DL/UL assignment/grant is detected, etc.) and PUSCH/PDSCH. K.sub.0 may denote delay between a DL grant (e.g., PDCCH, DCI) and corresponding DL data (e.g., PDSCH) reception. K.sub.2 may denote a delay between an UL grant (e.g., PDCCH, DCI) reception in the DL and corresponding UL data (e.g., PUSCH) transmission. Note that K.sub.0 and K.sub.2 above may be defined in units of slots, sub-slot(s) and/or symbol(s).

(134) The Time domain resource assignment field may be included in downlink control information (DCI) used for uplink (UL) grant and/or downlink (DL) assignment. For instance, the Time domain resource assignment field may be included in a DCI format(s) (e.g., the DCI format 0_0 and/or the DCI format 0_1 and/or the DCI format 0_2 and/or the DCI format 0_3) that is used for scheduling of the PUSCH. The Time domain resource assignment field may be included in a DCI format(s) (e.g., the DCI format 1_0 and/or the DCI format 1_1 and/or the DCI format 1_2 and/or the DCI format 1_3) that is used for scheduling of the PDSCH. The Time domain resource assignment field may be included in DCI (e.g., the DCI format 0_0, the DCI format 0_1, the DCI format 0_2 and/or the DCI format 0_3) used for activation of configured grant type 2. The Time domain resource assignment field may be included in DCI (e.g., the DCI format 1_0, the DCI format 1_1, the DCI format 1_2 and/or the DCI format 1_3) used for activation of DL semi-persistent scheduling (SPS). The Time domain resource assignment field (which may be referred to with a different name, e.g., timeDomainAllocation) may be included in radio resource control (RRC) signaling for configured grant type 1.

(135) The network may indicate in the downlink/uplink (DL/UL) assignment which of the configured time domain allocations (e.g., allocation table) the UE **102** may apply for that DL/UL assignment. There may be several defaulted allocation table(s) specified. In some examples, the default allocation table(s) may be defined only for the 4-bit Time domain resource assignment field. For instance, the default allocation table(s) may have 16 entities. And, the default allocation table(s) may also be defined for the more than 4-bit Time domain resource assignment field. For instance, in a case of a condition(s) that the default allocation table is used, the 4-bit Time domain resource assignment field may be always used for time-domain resource allocation (RA) (for the downlink, and/or for the uplink, for instance). The allocation table may be configured by using information included in the RRC message. Some examples are shown in the following listings. Listing (4) illustrates an example of a PUSCH-TimeDomainResourceAllocation information element. Listing (5) illustrates an example of a PDSCH-TimeDomainResourceAllocationList information element.

(136) TABLE-US-00004 Listing 4 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-START PUSCH-TimeDomainResourceAllocationList ::=

SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH- TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mapping Type ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-STOP -- ASN1STOP

(137) TABLE-US-00005 Listing-5 -- ASN1START -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-START PDSCH-TimeDomainResourceAllocationList ::= SEQUENCE (SIZE(1..maxNrofDL-Allocations)) OF PDSCH- TimeDomainResourceAllocation PDSCH-TimeDomainResourceAllocation ::= SEQUENCE { k0 INTEGER(0..32) OPTIONAL, -- Need S mapping Type ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) } -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-STOP -- ASN1STOP

The UE **102** may determine the number of bits (e.g., the bit width, the size) of the Time domain resource assignment field based on the number of entries in the allocation table. As described above, the number of entries may be determined (e.g., configured) based on the information included in the RRC message. In some examples, the maximum number of entries in the configured allocation table (e.g., maxNrofUL-Allocations or maxNrofDL-Allocations) may be set as 16 (or 32 or 64). In some examples, the maximum number of entries in the defaulted allocation table(s) may be 16 (or 32 or 64). In this case, the number of bits (e.g., the maximum number of bits) of the Time domain resource assignment field may be 4 (or 5 or 6). For example, the number of bits of the Time domain resource assignment field in a fallback DCI (e.g., the DCI Format 0_0, or the DCI Format 1_0) may be 4. The number of bits of the Time domain resource assignment field in non-fallback DCI (e.g., the DCI Format 0_1, or the DCI Format 1_1, the DOI Format 0_2, or the DCI Format 1_2, the DCI Format 0_3, or the DCI Format 1_3) may be 0, 1, 2, 3, 4, 5 or 6.

(138) In some examples, 16 entries (i.e., 16 time domain allocations) in the allocation table may not be enough to meet the flexible scheduling, dynamic indication of the number of repetitions, or other requirements. Thus, in a different implementation, an allocation table with more than 16 entries may be configured by using information included in the RRC message. For instance, the number of entries (e.g., the maximum number of entries) in the configured allocation table (e.g., maxNrofUL-Allocations1 or maxNrofDL-Allocations1) may be set greater than 16 (e.g., 32 or 64). Additionally or alternatively, one or more defaulted allocation tables with more than 16 entries may be defined. In this case, more than 4 bits may be needed for the Time domain resource assignment field. For instance, the UE **102** may need to identify a 4-bit Time domain resource assignment field and/or a more than 4-bit Time domain resource assignment field (e.g., 5-bit or 6-bit Time domain resource assignment field).

(139) As mentioned above, to support the dynamic indication of the number of repetitions for dynamic grant and/or configured grant, the number of repetitions may be jointly coded with SLIV in a TDRA table, by adding an additional column for the number of repetitions in the TDRA table (default table(s) and/or RRC configured table(s)). The maximum TDRA table size may be increased to 64. Start symbol S and length L may be used instead of SLIV. The TDRA table may be configured per DCI format. Some examples are shown in the following listings. Listing 6 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat0_1 (as well as PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1) information element. Listing 7 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat0_2 (as well as PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2) information element. Listing 8 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat0_2 (as well as PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2) information element with separate start symbol S and length L instead of startSymbolAndLength SLIV.

(140) TABLE-US-00006 Listing 6 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_1-S TART PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat0_1 ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_1- STOP -- ASN1STOP

(141) TABLE-US-00007 Listing 7 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_2-S TART PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat0_2 ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_2- STOP -- ASN1STOP

(142) TABLE-US-00008 Listing 8 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_2-S TART PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF

PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat0_2 ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbol INTEGER (0..13) Length INTEGER (1..14) numberofrepetitions INTEGER (0..8) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_2- STOP -- ASN1STOP
To support NR light, a new TDRA table may be introduced/configured for NR light service and/or DCI format 0_3/1_3. The maximum TDRA table size may be increased to 64. Start symbol S and length L may be used instead of SLIV. The TDRA table may be configured per DCI format or per specific NR light service. Some examples are shown in the following listings. Listing 9 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForNR_light (as well as PUSCH-TimeDomainResourceAllocationList-ForNR_light) information element. Listing 10 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat0_3 (as well as PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3) information element. Listing 11 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat0_3 (as well as PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3) information element with separate start symbol S and length L instead of startSymbolAndLength SLIV. Additionally or alternatively, a default TDRA table be provided for NR light only.

(143) TABLE-US-00009 Listing 9 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORNR_LIGH T-START PUSCH-TimeDomainResourceAllocationList-ForNR_light ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForNR_light ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mapping Type ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORNR_LIG HT-STOP -- ASN1STOP

(144) TABLE-US-00010 Listing 10 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_3-S TART PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat0_3 ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } . -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_3- STOP -- ASN1STOP

(145) TABLE-US-00011 Listing 11 -- ASN1START -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_3- START PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PUSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat0_3 ::= SEQUENCE { k2 INTEGER(0..32) OPTIONAL, -- Need S mapping Type ENUMERATED {typeA, typeB}, startSymbol INTEGER (0..13) Length INTEGER (1..14) numberofrepetitions INTEGER (0..8) } -- TAG-PUSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT0_3 -STOP -- ASN1STOP
As mentioned above, there may be multiple TDRA tables, e.g., PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config), pusch-TimeDomainAllocationList provided in a common RRC message (e.g., pusch-ConfigCommon), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 in UE-specific RRC message (e.g., PUSCH-Config), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 in a UE-specific RRC message (e.g., PUSCH-Config), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 in a UE-specific RRC message (e.g., PUSCH-Config) and/or default TDRA table(s) defined. Examples of determination of the resource allocation table to be used for PUSCH are described here. For example, if the UE **102** detects DCI format 0_1 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 is configured, PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 may be always applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_1, regardless of whether other table(s) (e.g., PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config), pusch-TimeDomainAllocationList provided in a common RRC message (e.g., pusch-ConfigCommon), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 in a UE-specific RRC message (e.g., PUSCH-Config)) is configured or not.

(146) If the UE **102** detects DCI format 0_2 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 is configured, PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 may be always applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or

activated) by the DCI format 0_2, regardless of whether other table(s) (e.g., PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config), pusch-TimeDomainAllocationList provided in a common RRC message (e.g., pusch-ConfigCommon), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 in a UE-specific RRC message (e.g., PUSCH-Config)) is configured or not. If the UE **102** detects DCI format 0_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 is configured, PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 may not be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_0.

(147) If the UE **102** detects DCI format 0_3 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 is configured, PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 may be always applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_3, regardless of whether other table(s) (e.g., PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config), pusch-TimeDomainAllocationList provided in a common RRC message (e.g., pusch-ConfigCommon), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 in a UE-specific RRC message (e.g., PUSCH-Config)), PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 in a UE-specific RRC message (e.g., PUSCH-Config)) is configured or not. If the UE **102** detects DCI format 0_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 is configured, PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 and/or PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 may not be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_0.

(148) If the UE **102** detects DCI format 0_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) is configured, PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_0, regardless of whether PUSCH-TimeDomainResourceAllocationList in a common RRC message (e.g., PUSCH-ConfigCommon) is configured or not. If the UE **102** detects DCI format 0_1 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_1 is not configured but PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) is configured, PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_1. If the UE **102** detects DCI format 0_2 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_2 is not configured but PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) is configured, PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_2. If the UE **102** detects DCI format 0_3 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PUSCH (and/or activation of configured grant Type 2) and PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3 is not configured but PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) is configured,

PUSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PUSCH-Config) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format 0_3.

(149) If the UE **102** detects a DCI format (e.g., DCI format 0_0, DCI format 0_1 or DCI format 0_2) in any common search space associated with CORESET 0 for scheduling of a PUSCH (and/or activation of configured grant Type 2) and there is no RRC configured TDRA table(s), the default table may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format. If the UE **102** detects a DCI format (e.g., DCI format 0_0, DCI format 0_1 or DCI format 0_2) in any common search space associated with CORESET 0 for scheduling of a PUSCH (and/or activation of configured grant Type 2) and only pusch-TimeDomainAllocationList in a common RRC message (e.g., pusch-ConfigCommon) is configured, pusch-TimeDomainAllocationList in a common RRC message (e.g., pusch-ConfigCommon) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format.

(150) If the UE **102** detects a DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2 or DCI format 0_3) in any common search space not associated with CORESET 0 and/or UE specific search space for scheduling of a PUSCH (and/or activation of configured grant Type 2) and there is no RRC configured TDRA table(s), the default table may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format. If the UE **102** detects a DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2 or DCI format 0_3) in any common search space not associated with CORESET 0 and/or UE specific search space for scheduling of a PUSCH (and/or activation of configured grant Type 2) and only pusch-TimeDomainAllocationList in a common RRC message (e.g., pusch-ConfigCommon) is configured, pusch-TimeDomainAllocationList in a common RRC message (e.g., pusch-ConfigCommon) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format.

(151) The selection of TDRA table may be determined by RNTI. If the UE **102** detects a DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2 or DCI format 0_3) with CRC scrambled by a NR light specific RNTI (e.g., L-RNTI, L-UL-RNTI), NR light specific TDRA table (e.g., PUSCH-TimeDomainResourceAllocationList-ForDCIformat0_3, PUSCH-TimeDomainResourceAllocationList-ForNR_light, the default table dedicated for NR light) may be applied for time domain resource allocation of the corresponding PUSCH transmission(s) (e.g., DG, CG Type 2, and/or retransmission of CG) scheduled (and/or activated) by the DCI format.

(152) To support NR light, a new TDRA table may be introduced/configured for NR light service and/or DCI format 0_3/1_3. The maximum TDRA table size may be increased to 64. Start symbol S and length L may be used instead of SLIV. The TDRA table may be configured per DCI format or per specific NR light service. Some examples are shown in the following listings. Listing 12 illustrates an example of a PDSCH-TimeDomainResourceAllocation-ForNR_light (as well as PDSCH-TimeDomainResourceAllocationList-ForNR_light) information element. Listing 13 illustrates an example of a PDSCH-TimeDomainResourceAllocation-ForDCIformat1_3 (as well as PDSCH-TimeDomainResourceAllocationList-ForDCformat1_3) information element. Listing 14 illustrates an example of a PUSCH-TimeDomainResourceAllocation-ForDCIformat1_3 (as well as PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3) information element with separate start symbol S and length L instead of startSymbolAndLength SLIV. Additionally or alternatively, a default TDRA table (for downlink) be provided for NR light only.

(153) TABLE-US-00012 Listing 12 ASN1START -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORNR_LIGH T-START PDSCH-TimeDomainResourceAllocationList-ForNR_light ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PDSCH-TimeDomainResourceAllocation PDSCH-TimeDomainResourceAllocation-ForNR_light ::= SEQUENCE { k0 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORNR_LIG HT-STOP -- ASN1STOP

(154) TABLE-US-00013 Listing 13 -- ASN1START -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT1_3- START PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PDSCH-TimeDomainResourceAllocation PDSCH-TimeDomainResourceAllocation-ForDCIformat1_3 ::= SEQUENCE { k0 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbolAndLength INTEGER (0..127) numberofrepetitions INTEGER (0..8) } -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT1_3 -STOP -- ASN1STOP

(155) TABLE-US-00014 Listing 14 -- ASN1START -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT1_3- START PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 ::= SEQUENCE (SIZE(1..maxNrofUL-Allocations)) OF PDSCH-TimeDomainResourceAllocation PUSCH-TimeDomainResourceAllocation-ForDCIformat1_3 ::=

SEQUENCE { k0 INTEGER(0..32) OPTIONAL, -- Need S mappingType ENUMERATED {typeA, typeB}, startSymbol INTEGER (0..13) Length INTEGER (1..14) numberofrepetitions INTEGER (0..8) } -- TAG-PDSCH-TIMEDOMAINRESOURCEALLOCATIONLIST-FORDCIFORMAT1_3 -STOP -- ASN1STOP

(156) As mentioned above, there may be multiple TDRA tables for downlink, e.g., PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config), pdsch-TimeDomainAllocationList provided in a common RRC message (e.g., pdsch-ConfigCommon), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 in UE-specific RRC message (e.g., PDSCH-Config), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 in a UE-specific RRC message (e.g., PDSCH-Config), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 in a UE-specific RRC message (e.g., PDSCH-Config) and/or default TDRA table(s) defined. Examples of determination of the resource allocation table to be used for PDSCH are described here. For example, if the UE **102** detects DCI format 1_1 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 is configured, PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 may be always applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_1, regardless of whether other table(s) (e.g., PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config), pdsch-TimeDomainAllocationList provided in a common RRC message (e.g., pdsch-ConfigCommon), PUSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 in a UE-specific RRC message (e.g., PDSCH-Config)) is configured or not.

(157) If the UE **102** detects DCI format 1_2 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 is configured, PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 may be always applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_2, regardless of whether other table(s) (e.g., PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config), pdsch-TimeDomainAllocationList provided in a common RRC message (e.g., pdsch-ConfigCommon), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 in a UE-specific RRC message (e.g., PDSCH-Config)) is configured or not. If the UE **102** detects DCI format 1_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 is configured, PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 may not be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_0.

(158) If the UE **102** detects DCI format 1_3 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 is configured, PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 may be always applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_3, regardless of whether other table(s) (e.g., PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config), pdsch-TimeDomainAllocationList provided in a common RRC message (e.g., pdsch-ConfigCommon), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 in a UE-specific RRC message (e.g., PDSCH-Config)), PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 in a UE-specific RRC message (e.g., PDSCH-Config)) is configured or not. If the UE **102** detects DCI format 1_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 is configured, PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 and/or PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 may not be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_0.

(159) If the UE **102** detects DCI format 1_0 (in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList in a UE-

specific RRC message (e.g., PDSCH-Config) is configured, PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_0, regardless of whether PDSCH-TimeDomainResourceAllocationList in a common RRC message (e.g., PDSCH-ConfigCommon) is configured or not. If the UE **102** detects DCI format 1_1 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_1 is not configured but PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) is configured, PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_1. If the UE **102** detects DCI format 1_2 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_2 is not configured but PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) is configured, PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_2. If the UE **102** detects DCI format 1_3 (e.g., in any common search space associated with CORESET 0, in any common search space not associated with CORESET 0, and/or UE specific search space, for instance) for scheduling of a PDSCH (and/or activation of SPS) and PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3 is not configured but PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) is configured, PDSCH-TimeDomainResourceAllocationList in a UE-specific RRC message (e.g., PDSCH-Config) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format 1_3.

(160) If the UE **102** detects a DCI format (e.g., DCI format 1_0, DCI format 1_1 or DCI format 1_2) in any common search space associated with CORESET 0 for scheduling of a PDSCH (and/or activation of SPS) and there is no RRC configured TDRA table(s), the default table may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format. If the UE **102** detects a DCI format (e.g., DCI format 1_0, DCI format 1_1 or DCI format 1_2) in any common search space associated with CORESET 0 for scheduling of a PDSCH (and/or activation of SPS) and only pusch-TimeDomainAllocationList in a common RRC message (e.g., pdsch-ConfigCommon) is configured, pdsch-TimeDomainAllocationList in a common RRC message (e.g., pdsch-ConfigCommon) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format.

(161) If the UE **102** detects a DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2 or DCI format 1_3) in any common search space not associated with CORESET 0 and/or UE specific search space for scheduling of a PDSCH (and/or activation of SPS) and there is no RRC configured TDRA table(s), the default table may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format. If the UE **102** detects a DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2 or DCI format 1_3) in any common search space not associated with CORESET 0 and/or UE specific search space for scheduling of a PDSCH (and/or activation of SPS) and only pdsch-TimeDomainAllocationList in a common RRC message (e.g., pdsch-ConfigCommon) is configured, pdsch-TimeDomainAllocationList in a common RRC message (e.g., pdsch-ConfigCommon) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format.

(162) The selection of TDRA table may be determined by RNTI. If the UE **102** detects a DCI format (e.g., DCI format 1_0, DCI format 1_1, DCI format 1_2 or DCI format 1_3) with CRC scrambled by a NR light specific RNTI (e.g., L-RNTI, L-DL-RNTI), NR light specific TDRA table (e.g., PDSCH-TimeDomainResourceAllocationList-ForDCIformat1_3, PDSCH-TimeDomainResourceAllocationList-ForNR_light, the default table dedicated for NR light) may be applied for time domain resource allocation of the corresponding PDSCH transmission(s) (e.g., DG, SPS, and/or retransmission of SPS) scheduled (and/or activated) by the DCI format.

(163) A set of PDCCH candidates for a UE **102** to monitor may be defined in terms of PDCCH search space sets. A search space set may be a common search space set or a UE-specific search space set. A UE **102** may monitor PDCCH candidates in one or more of the search spaces sets including a Type3-PDCCH common search space set configured by SearchSpace in PDCCH-Config with searchSpaceType=common for DCI formats with CRC scrambled by INT-RNTI, SFI-RNTI, TPC-PUSCH-RNTI, TPC-PUCCH-RNTI, or TPC-SRS-RNTI and, only for the primary cell, C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) or CS-RNTI(s); and a

UE-specific search space set configured by SearchSpace in PDCCH-Config with searchSpaceType=ue-Specific for DCI formats with CRC scrambled by C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) or CS-RNTI(s). An example of SearchSpace configuration is shown in Listing 15.

(164) TABLE-US-00015 Lisiting 15 -- ASN1START -- TAG-SEARCHSPACE-START SearchSpace : := SEQUENCE { searchSpaceId SearchSpaceId, controlResourceSetId ControlResourceSetId OPTIONAL, -- Cond SetupOnly monitoringSlotPeriodicityAndOffset CHOICE { s11 NULL, s12 INTEGER (0..1), s14 INTEGER (0..3), s15 INTEGER (0..4), s18 INTEGER (0..7), s110 INTEGER (0..9), s116 INTEGER (0..15), s120 INTEGER (0..19), s140 INTEGER (0..39), s180 INTEGER (0..79), s1160 INTEGER (0..159), s1320 INTEGER (0..319), s1640 INTEGER (0..639), s11280 INTEGER (0..1279), s12560 INTEGER (0..2559) } OPTIONAL, -- Cond Setup duration INTEGER (2..2559) OPTIONAL, -- Need R monitoringSymbolsWithinSlot BIT STRING (SIZE (14)) OPTIONAL, -- Cond Setup nrofCandidates SEQUENCE { aggregationLevel1 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}, aggregationLevel2 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}, aggregationLevel4 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}, aggregationLevel8 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8}, aggregationLevel16 ENUMERATED {n0, n1, n2, n3, n4, n5, n6, n8} } OPTIONAL, -- Cond Setup searchSpaceType CHOICE { common SEQUENCE { dci-Format0-0-AndFormat1-0 SEQUENCE { . . . } OPTIONAL, -- Need R dci-Format2-0 SEQUENCE { nrofCandidates-SFI SEQUENCE { aggregationLevel1 ENUMERATED {n1, n2} OPTIONAL, -- Need R aggregationLevel2 ENUMERATED {n1, n2} OPTIONAL, -- Need R aggregationLevel4 ENUMERATED {n1, n2} OPTIONAL, -- Need R aggregationLevel8 ENUMERATED {n1, n2} OPTIONAL, -- Need R aggregationLevel16 ENUMERATED {n1, n2} OPTIONAL -- Need R }, . . . } OPTIONAL, -- Need R dci-Format2-1 SEQUENCE { . . . } dci-Format2-1* SEQUENCE { . . . } OPTIONAL, -- Need R dci-Format2-2 SEQUENCE { . . . } OPTIONAL, -- Need R dci-Format2-3 SEQUENCE { monitoringPeriodicity ENUMERATED {n1, n2, n4, n5, n8, n10, n16, n20 } OPTIONAL, -- Cond Setup nrofPDCCH-Candidates ENUMERATED {n1, n2}, ... dci-Format0-3 SEQUENCE { monitoringPeriodicity ENUMERATED {n1, n2, n4, n5, n8, n10, n16, n20 } OPTIONAL, -- Cond Setup nrofPDCCH-Candidates ENUMERATED {n1, n2}, . . . dci-Format1-3 SEQUENCE { monitoringPeriodicity ENUMERATED {n1, n2, n4, n5, n8, n10, n16, n20 } OPTIONAL, -- Cond Setup nrofPDCCH-Candidates ENUMERATED {n1, n2}, . . . } OPTIONAL -- Need R }, ue-Specific SEQUENCE { dci-Formats ENUMERATED { formats0-0-And-1-0, formats0-1-And-1-1, formats0-2-And-1-2, formats0-3-And-1-3}, ... } } OPTIONAL -- Cond Setup } -- TAG-SEARCHSPACE-STOP -- ASN1STOP_

(165) UE may monitor a set of PDCCH candidates in one or more CORESETs on the active DL BWP on each activated serving cell configured with PDCCH monitoring according to corresponding search space sets where monitoring implies decoding each PDCCH candidate according to the monitored DCI formats. For each DL BWP configured to a UE in a serving cell, a UE can be provided by higher layer signalling with P≤3 CORESETs. For each CORESET, the UE is provided the following by ControlResourceSet: a CORESET index p, 0≤p<12, by controlResourceSetId; a DM-RS scrambling sequence initialization value by pdcch-DMRS-ScramblingID; a precoder granularity for a number of REGs in the frequency domain where the UE can assume use of a same DM-RS precoder by precoderGranularity; a number of consecutive symbols provided by duration; a set of resource blocks provided by frequencyDomainResources; CCE-to-REG mapping parameters provided by cce-REG-MappingType; an antenna port quasi co-location, from a set of antenna port quasi co-locations provided by TCI-State, indicating quasi co-location information of the DM-RS antenna port for PDCCH reception in a respective CORESET; an indication for a presence or absence of a transmission configuration indication (TCI) field for DCI

format 1_1 (DCI format 1_2, or DCI format 1_3) transmitted by a PDCCH in CORESET p, by TCI-PresentInDCI. An example of the IE ControlResourceSet used to configure a time/frequency control resource set (CORESET) in which to search for downlink control information is shown in Listing 16.

(166) TABLE-US-00016 Listing 16 -- ASN1START -- TAG-CONTROLRESOURCESET-START ControlResourceSet : := SEQUENCE { controlResourceSetId ControlResourceSetId, frequencyDomainResources BIT STRING (SIZE (45)), duration INTEGER (1..maxCoReSetDuration), cce-REG-MappingType CHOICE { interleaved SEQUENCE { reg-BundleSize ENUMERATED {n2, n3, n6}, interleaverSize ENUMERATED {n2, n3, n6}, shiftIndex INTEGER (0..maxNrofPhysicalResourceBlocks-1) OPTIONAL -- Need S }, nonInterleaved NULL }, precoderGranularity ENUMERATED {sameAsREG-bundle, allContiguousRBs}, tci-StatesPDCCH-ToAddList SEQUENCE (SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP tci-StatesPDCCH-ToReleaseList SEQUENCE (SIZE (1..maxNrofTCI-StatesPDCCH)) OF TCI-StateId OPTIONAL, -- Cond NotSIB1-initialBWP tci-PresentInDCI ENUMERATED {enabled} OPTIONAL, -- Need S pdcch-DMRS-ScramblingID INTEGER (0..65535) OPTIONAL, -- Need S . . . } -- TAG-CONTROLRESOURCESET-STOP -- ASN1STOP

If DCI format 0_3 and/or DCI format 1_3 is introduced, a UE **102** may monitor PDCCH candidates in a new common search space which may be referred to as Type4-PDCCH common search space set configured by higher layer parameter SearchSpaceNRlight in PDCCH-Config with searchSpaceType=common for DCI formats with CRC scrambled by C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) or CS-RNTI(s). The higher layer parameter SearchSpaceNRlight may provide monitoring periodicity and an offset, a number of consecutive slots that a search space lasts in every occasion, symbols for PDCCH monitoring in the slots configured for PDCCH monitoring, a number of PDCCH candidates per aggregation level, an identity of the search space, a search space type indicating whether this is a common search space (present) and/or a UE-specific search space as well as DCI formats to monitor.

(167) If DCI format 0_3 and/or DCI format 1_3, a UE **102** may reuse an existing Type3-PDCCH common search space set configured by higher layer parameter SearchSpace in PDCCH-Config with searchSpaceType=common with a newly introduced DCI format (e.g., dci-Format0-3 and/or dci-Format1-3 in Listing 12) and/or other parameters described above. If dci-Format0-3 is configured, the UE **102** may monitor the DCI format 0_3 with CRC scrambled by C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI) or CS-RNTI(s). If dci-Format1-3 is configured, the UE **102** may monitor the DCI format 1_3 with CRC scrambled by C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-DL-RNTI) or CS-RNTI(s).

(168) If DCI format 0_3 and/or DCI format 1_3 is introduced, a UE **102** may reuse the UE-specific search space set configured by SearchSpace in PDCCH-Config with searchSpaceType=ue-Specific with a newly introduced DCI format (e.g., formats0-3-And-1-3 in Listing 12) and/or other parameters mentioned above. If the parameter dci-Formats in ue-Specific indicates formats0-3-And-1-3, it configures this search space as UE-specific search space (USS). The UE **102** may monitor the DCI format (DCI format 0_3 and/or DCI format 1_3) with CRC scrambled by C-RNTI, MCS-C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) or CS-RNTI(s).

(169) A UE **102** may monitor PDCCH conveying DCI format 0_3 and/or DCI format 1_3 in the common search space set and/or the UE-specific search space. For example, the UE **102** may monitor PDCCH candidates in one or more of the following search spaces sets: a Type1-PDCCH common search space set configured by ra-SearchSpace (e.g., a higher layer parameter) for a DCI format(s) with CRC scrambled by a RA-RNTI, and/or a TC-RNTI; a Type3-PDCCH common search space set configured by SearchSpace (e.g., a higher layer parameter) with searchSpaceType=common for a DCI format(s) with CRC scrambled by INT-RNTI, INT-UL-RNTI, C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) and/or CS-RNTI(s); and a UE-specific search space set configured by SearchSpace (e.g., the higher layer parameter) with searchSpaceType=ue-Specific for a DCI format(s) with CRC scrambled by C-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) or CS-RNTI(s).

(170) Also, for example, for each DL BWP configured to a UE in a serving cell, the UE is provided by a higher layer parameter with S≤10 search space sets where, for each search space set from the S search space sets, the UE **102** may be provided one or more of the following by a higher layer parameter SearchSpace: a search space set index s, 0≤s<40, by a higher layer parameter searchSpaceId; an association between the search space set s and a control resource set p by a higher layer parameter controlResourceSetId; a PDCCH monitoring periodicity of k.sub.p,s slots and a PDCCH monitoring offset of o.sub.p,s slots, by a higher layer parameter monitoringSlotPeriodicityAndOffset; a PDCCH monitoring pattern within a slot, indicating first symbol(s) of the control resource set within a slot for PDCCH monitoring, by a higher layer parameter monitoringSymbolsWithinSlot; a number of PDCCH candidates M.sub.p,s.sup.(L) per CCE aggregation level L by a higher layer parameters aggregationLevel1, aggregationLevel2, aggregationLevel4, aggregationLevel8, and aggregationLevel16, for CCE aggregation level 1, CCE aggregation level 2, CCE aggregation level 4, CCE aggregation level 8, and CCE aggregation level 16, respectively, an indication that search space set s is either a common search space set or a UE-specific search space set by a higher

layer parameter searchSpaceType.

(171) If the search space set s is a common search space set, then the UE **102** is provided the following by a higher layer parameter SearchSpace: an indication by higher layer parameter dci-Format0-0-AndFormat1-0 to monitor PDCCH candidates for DCI format 0_0 and DCI format 1_0 with CRC scrambled by a C-RNTI, a CS-RNTI, RA-RNTI, new RNTI (e.g., L-RNTI, L-UL-RNTI, L-DL-RNTI) and/or TC-RNTI; an indication by higher layer parameter dci-Format0-3 to monitor PDCCH candidates for DCI format 0_3; an indication by higher layer parameter dci-Format1-3 to monitor PDCCH candidates for DCI format 1_3.

(172) If the search space set s is a UE-specific search space set, then the UE **102** is provided the following by a higher layer parameter SearchSpace: an indication by a higher layer parameter dci-Formats to monitor PDCCH candidate either for DCI format 0_0 and DCI format 1_0, or for DCI format 0_1 and DCI format 1_1, or for DCI format 0_2 and DCI format 1_2, or for DCI format 0_3 and DCI format 1_3.

(173) Here, the UE **102** may determine a PDCCH monitoring occasion(s) from the PDCCH monitoring periodicity, the PDCCH monitoring offset, and/or the PDCCH monitoring pattern within a slot. As described above, for example, for each search space set, DCI format 0_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-UL-RNTI) and/or DCI format 1_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-DL-RNTI) may be independently configured. For example, the PDCCH monitoring occasion(s) may be independently configured for DCI format 0_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-UL-RNTI) and/or DCI format 1_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-DL-RNTI).

(174) Here, for each search space set, DCI format 0_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-UL-RNTI) and/or DCI format 1_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-DL-RNTI) may be commonly configured. For example, the PDCCH monitoring occasion(s) may be commonly configured for DCI format 0_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-UL-RNTI) and/or DCI format 1_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-DL-RNTI). For example, the gNB **160** may configure for the UE **102** to monitor the PDCCH candidates for the DCI format 0_3, and, the UE **102** may monitor, based on the parameter(s) as described above, both of the DCI format 0_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-UL-RNTI) and/or DCI format 1_3 with CRC scrambled by new RNTI (e.g., L-RNTI, L-DL-RNTI).

(175) To support reduced capability UE(s) and its service(s), reduced PDCCH monitoring by smaller numbers of blind decodes and CCE limits may be needed (for the search space of new DCI format (e.g., DCI format 0_3 and/or DCI format 1_3) if the new DCI format is configured for UE with reduced capability and/or the search space of existing DCI format (e.g., DCI format 0_0, DCI format 0_1, DCI format 0_2, DCI format 1_0, DCI format 1_1, and/or DCI format 1_2) if the existing DCI format is configured for UE with reduced capability). Monitoring periodicity may be separately configured for NR light and the value(s) may be larger than 1 slot. Monitoring occasion(s) within a slot (e.g., monitoringSymbolsWithinSlot) may be configured separately configured for NR light and the number of monitoring occasion(s) within a slot may not be larger than 1 (e.g., only 1 monitoring symbol is indicated by higher layer parameter monitoringSymbolsWithinSlot). Number of PDCCH candidates (per CCE aggregation level) may be configured separately configured for NR light and the number of PDCCH candidates may be limited (e.g., only 1 is supported).

(176) The behavior/procedure/configuration described in the disclosure for reduced capability UE may be treated as a UE feature. The UE feature may be configured to a UE by RRC message (e.g., UE Capability Information). If the UE is configured with the reduced capability UE feature by the RRC message, the UE may use NR light specific configuration(s), NR light specific DCI format(s), NR light specific parameter(s)/table(s) and/or NR light specific procedure(s) as mentioned above.

(177) There may be multiple (e.g., sets of) reduced/relaxed UE processing, preparation and/or timing capabilities (RedCap). High-end devices may use a less reduced and/or relaxed UE processing and/or preparation/timing capability, while low-end devices may use a more reduced and/or relaxed UE processing, preparation and/or timing capability. Reduced capability NR devices may support multiple (e.g., sets of) reduced and/or relaxed UE processing, preparation and/or timing capabilities. The reduced capability NR devices may select and/or switch between/among the multiple (e.g., sets of) reduced and/or relaxed UE processing, preparation and/or timing capabilities. The specific reduced and/or relaxed UE processing, preparation and/or timing capabilities used by reduced/relaxed UE processing/preparation/timing capabilities may be RRC configured, a high layer parameter provided by a dedicated/UE-specific RRC message may indicate the RedCap from a set. For example, a first RedCap (e.g., Reduced UE capability 1) may be defined for high-end reduced capability NR devices and/or high-end reduced capability services, while a second RedCap (e.g., Reduced UE capability 1) may be defined for low-end reduced capability NR devices and/or low-end reduced capability services. Reduced capability NR devices may support only one reduced UE capability, either the first RedCap or the second RedCap. Reduced capability NR devices may support both reduced UE capabilities. In the case that multiple reduced UE capabilities are supported by a UE, a high layer parameter RedCapType provided by a dedicated/UE-specific RRC message may indicate the reduced UE capability for the UE. If the high layer parameter RedCapType is provided and set as RedCap1, the first RedCap (e.g., Reduced UE capability 1) may be applied to the UE. If the high layer parameter RedCapType is

provided and set as RedCap2, the second RedCap (e.g., Reduced UE capability 2) may be applied to the UE. If the high layer parameter RedCapType is not provided, the first RedCap (e.g., Reduced UE capability 1) may be applied to the RedCap UE. If the high layer parameter RedCapType is not provided, the second RedCap (e.g., Reduced UE capability 2) may be applied to the RedCap UE. In the case that multiple (e.g., sets of) reduced/relaxed UE processing/preparation/timing capabilities, procedures and parameters (e.g., DCI format configurations, fields, bit-width, values, processing/procedure/preparation time, etc. as mentioned in this disclosure) for each reduced/relaxed UE processing/preparation/timing capability may be defined/configured/designed/provided separately.

(178) As a different capability, the number of decodable TBs with different sizes in a slot (pdsch-ProcessingType1-DifferentTB-PerSlot) may be specified for type 1 capability and the minimum value is 2. A RedCap UE can alternately transmit the capabilities (pdsch-ProcessingType3-DifferentTB-PerSlot) to a gNB. pdsch-ProcessingType1-DifferentTB-PerSlot can be 2, 4, 6, etc. pdsch-ProcessingType3-DifferentTB-PerSlot can be 1, 2, 4, etc.

(179) As a different capability, the number of decodable TBs with different sizes in a slot (pusch-ProcessingType1-DifferentTB-PerSlot) may be specified for type 1 capability and the minimum value is 2. A RedCap UE can alternately transmit the capabilities (pusch-ProcessingType3-DifferentTB-PerSlot) to a gNB. pusch-ProcessingType1-DifferentTB-PerSlot can be 2, 4, 6, etc. pusch-ProcessingType3-DifferentTB-PerSlot can be 1, 2, 4, etc.

(180) UE PDSCH processing procedure time is described herein. If the first uplink symbol of the PUCCH which carries the HARQ-ACK information, as defined by the assigned HARQ-ACK timing K.sub.1 and the PUCCH resource to be used and including the effect of the timing advance, starts no earlier than at symbol L.sub.1, where L.sub.1 is defined as the next uplink symbol with its CP starting T.sub.proc,1 after the end of the last symbol of the PDSCH carrying the TB being acknowledged, then the UE may provide a valid HARQ-ACK message. Otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH. The value of T.sub.proc,1 is used both in the case of normal and extended cyclic prefix. T.sub.proc,1 may be referred to as UE PDSCH processing time or UE PDSCH processing procedure time.

(181) The UE PDSCH processing time T.sub.proc,1 may be determined by PDSCH decoding time N.sub.1[symbols]. N.sub.1 is based on numerology μ for different UE processing capabilities (e.g., capability 1, 2 or new capability, reduced capability), where μ corresponds to the one of (μ.sub.PDCCH, μ.sub.PDSCH, μ.sub.UL) resulting with the largest T.sub.proc,1, where the μ.sub.PDCCH corresponds to the subcarrier spacing of the PDCCH scheduling the PDSCH, the μ.sub.PDSCH corresponds to the subcarrier spacing of the scheduled PDSCH, and μ.sub.UL corresponds to the subcarrier spacing of the uplink channel with which the HARQ-ACK is to be transmitted. μ may be the index of numerology and the subcarrier spacing is given by Δf=2.sup.μ.Math.15 [kHz]. PDSCH decoding time N.sub.1 may also be determined by DMRS configurations (e.g., DMRS position, additional position, mapping type). Examples of PDSCH decoding time (also referred to as processing time) for PDSCH processing capability 1 are shown in Table 1. Examples for PDSCH decoding time for PDSCH processing capability 2 are shown Table 2.

(182) TABLE-US-00017 TABLE 1 PDSCH decoding time N.sub.1 [symbols] dmrs-AdditionalPosition ≠ pos0 in DMRS-DownlinkConfig in either of dmrs-AdditionalPosition = pos0 in dmrs-DownlinkForPDSCH-MappingTypeA, DMRS-DownlinkConfig in both of dmrs-DownlinkForPDSCH-MappingTypeB dmrs-DownlinkForPDSCH-MappingTypeA, or if the higher layer parameter is not μ dmrs-DownlinkForPDSCH-MappingTypeB configured 0 8 N{dot over (.sub.1, 0)} 1 10 13 2 17 20 3 20 24

(183) TABLE-US-00018 TABLE 2 PDSCH decoding time N.sub.1 [symbols] dmrs-AdditionalPosition = pos0 in DMRS-DownlinkConfig in both of dmrs-DownlinkForPDSCH-MappingTypeA, μ dmrs-DownlinkForPDSCH-MappingTypeB 0 3 1 4.5 2 9 for frequency range 1

(184) PDSCH decoding time N.sub.1 may be determined by the PDSCH DM-RS position. For example, if the PDSCH DM-RS position l.sub.1 for the additional DM-RS is l.sub.1=12, then N.sub.1,0=14 in Table 1, otherwise N.sub.1,0=13.

(185) The UE PDSCH processing procedure time may be also determined by carrier aggregation. For example, if the UE is configured with multiple active component carriers, the first uplink symbol which carries the HARQ-ACK information further includes the effect of timing difference between the component carriers.

(186) The UE PDSCH processing T.sub.proc,1 may be determined by PDSCH mapping type, and/or number of PDSCH symbols allocated, and/or scheduled RB allocation. For example, the UE PDSCH processing T.sub.proc,1 may be given by T.sub.proc,1=(N.sub.1+d.sub.1,1) (2048+144).Math.κ2.sup.−μ.Math.T.sub.C. Throughout this description, unless otherwise noted, the size of various fields in the time domain is expressed in time units T.sub.c=1/(Δf.sub.max.Math.N.sub.f), where Δf.sub.max=480.Math.10.sup.3 Hz and N.sub.f=4096. The constant κ=T.sub.s/T.sub.c=64, Where T.sub.s=1/(Δf.sub.ref.Math.N.sub.f,ref), Δf.sub.ref=15.Math.10.sup.3 Hz and N.sub.f,ref=2048. For the PDSCH mapping type A, if the last symbol of PDSCH is on the i-th symbol of the slot where i<7, then d.sub.1,1=7−i, otherwise d.sub.1,1=0. For UE processing capability 1 and PDSCH mapping type B, if the number of PDSCH symbols allocated is L≥7, then d.sub.1,1=0; if the number of PDSCH symbols allocated is

L≥4 and L≤6, then d.sub.1,1=7−L; if the number of PDSCH symbols allocated is L=3 then d.sub.1,1=3+min (d,1), where d is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH; if the number of PDSCH symbols allocated is 2, then d.sub.1,1=3+d, where d is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH. For UE processing capability 2 and PDSCH mapping type B, if the number of PDSCH symbols allocated is L≥7, then d.sub.1,1=0; if the number of PDSCH symbols allocated is L≥3 and L≤6, then d.sub.1,1 is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH; if the number of PDSCH symbols allocated is 2, if the scheduling PDCCH was in a 3-symbol CORESET and the CORESET and the PDSCH had the same starting symbol, then d.sub.1,1=3, otherwise d.sub.1,1 is the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH. For UE processing capability 2 with scheduling limitation when μ.sub.PDSCH=1, if the scheduled RB allocation exceeds 136 RBs, the UE defaults to capability 1 processing time. The UE may skip decoding a number of PDSCHs with last symbol within 10 symbols before the start of a PDSCH that is scheduled to follow Capability 2, if any of those PDSCHs are scheduled with more than 136 RBs with 30 kHz SCS and following Capability 1 processing time.
(187) Whether to apply UE processing capability 2 or not may be RRC configured. For example, for a UE that supports capability 2 on a given cell, the processing time according to UE processing capability 2 is applied if the high layer parameter processingType2Enabled in PDSCH-ServingCellConfig is configured for the cell and set to enable.
(188) To support reduced capability NR devices, relaxed UE PDSCH processing procedure time and/or reduced UE processing capability (new capability) may be introduced. Definitions and/or methods for relaxed UE PDSCH processing procedure time may be introduced as described in the following.
(189) Relaxed PDSCH decoding time N.sub.1_relaxed may be introduced. N.sub.1_relaxed may be based on numerology μ for the reduced UE processing capability (new capability), where μ corresponds to the one of the following parameters: μ.sub.PDCCH, μ.sub.PDSCH, μ.sub.UL (e.g., the parameter resulting with the largest processing time. For reduced UE capability, large subcarrier spacing may not be supported. Namely, p may be selected from small values (e.g., 0, 1, 2). Subcarrier spacing less than 15 kHz may be supported (e.g., 7.5 kHz and 3.75 kHz, etc.). Namely, μ may be −1, or −2, etc. Relaxed PDSCH decoding time N.sub.1_relaxed may also be determined by DMRS configurations (e.g., DMRS position, additional position, mapping type). DMRS configurations may be separately configured for reduced capability UE. DMRS configurations (e.g., DMRS position, additional position, mapping type), may be newly designed/introduced for a reduced capability UE. The formula and/or methods to calculate the relaxed UE PDSCH processing time (e.g., by taking into account DMRS configuration) may be different from PDSCH processing capability 1 and PDSCH processing capability 2.
(190) In an example, a new table, which is different from the examples of PDSCH decoding time for PDSCH processing capability 1 and for PDSCH processing capability 2 shown in Table 1 and Table 2, may be introduced for the relaxed PDSCH decoding time N.sub.1_relaxed. The value of N.sub.1_relaxed [symbols] may be larger than the value of N, for PDSCH processing capability 1 and for PDSCH processing capability 2. The number of rows in the new table may be less than the number of rows in the tables for PDSCH processing capability 1 and for PDSCH processing capability 2, since less numerologies may be supported for the relaxed processing time. The value of N.sub.1_relaxed may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. Whether the new table is applied for the relaxed processing time or not may be RRC configured. For example, for a UE that supports reduced UE processing capability (new capability) on a given cell, the processing time according to reduced UE processing capability (i.e., processing time determined by the new table for the relaxed PDSCH decoding time N.sub.1_relaxed), may be applied if the high layer parameter processingRelaxedEnabled in PDSCH-ServingCellConfig is configured for the cell and/or set to enable. Some examples of PDSCH processing time for relaxed PDSCH processing capability are shown in Table 3, Table 4 and Table 5. In Table 4, there are two reduced UE capabilities. One is reduced UE capability 1 for high-end reduced capability devices and/or services and the other is reduced UE capability 2 for low-end reduced capability devices and/or services. Each reduced UE capability has a set of PDSCH decoding time. If the high layer parameter RedCapType is provided and set as RedCap1, the first RedCap (Reduced UE capability 1) may be applied to the UE (e.g., the PDSCH decoding time N.sub.1_relaxed is given by the column of Reduced UE capability 1. If the high layer parameter RedCapType is provided and set as RedCap2, the second RedCap (Reduced UE capability 2) may be applied to the UE (e.g., the PDSCH decoding time N.sub.1_relaxed is given by the column of Reduced UE capability 2). If the high layer parameter processingRelaxedEnabled in PDSCH-ServingCellConfig is configured for the cell and/or set to enable and the high layer parameter RedCapType is not provided, the first RedCap (Reduced UE capability 1) may be applied to the UE (e.g., the PDSCH decoding time N.sub.1_relaxed is given by the column of Reduced UE capability 1. In yet another design, if the high layer parameter processingRelaxedEnabled in PDSCH-ServingCellConfig is configured for the cell and/or set to enable and the high layer parameter RedCapType is not provided, the second RedCap (Reduced UE capability 2) may be applied to the UE (e.g., the PDSCH decoding time N.sub.1_relaxed is given by the column of Reduced UE capability 2).
(191) TABLE-US-00019 TABLE 3 PDSCH decoding time N.sub.1, relaxed [symbols] dmrs-AdditionalPosition ≠

pos0 in DMRS-DownlinkConfig in either of dmrs-AdditionalPosition = pos0 in dmrs-DownlinkForPDSCH-MappingTypeA, DMRS-DownlinkConfig in both of dmrs-DownlinkForPDSCH-MappingTypeB dmrs-DownlinkForPDSCH-MappingTypeA, or if the higher layer parameter is not μ dmrs-DownlinkForPDSCH-MappingTypeB configured 0 13 20 1 20 23 2 24 28 3 28 32

(192) TABLE-US-00020 TABLE 4 PDSCH decoding time N.sub.1, relaxed [symbols] Reduced UE capability 1 Reduced UE capability 2 (low-end μ (high-end devices/services) devices/services, e.g., wearable) 0 13 20 1 20 23 2 24 28 3 28 32

(193) TABLE-US-00021 TABLE 5 PDSCH decoding time N.sub.1, relaxed [symbols] dmrs-AdditionalPosition = pos0 in DMRS-DownlinkConfig in both of dmrs-DownlinkForPDSCH-MappingTypeA, μ dmrs-DownlinkForPDSCH-MappingTypeB −2 8 −1 10 0 17 1 20 2 24

In yet another example, a scaling factor may be introduced and/or configured for the relaxed processing time. The value of N.sub.1_relaxed may be the value of N.sub.1 for PDSCH processing capability 1 (or the value of N.sub.1 for PDSCH processing capability 2) times the scaling factor. The scaling factor may be fixed in the specification, or RRC configured. The value of the scaling factor may be selected from a set of values (e.g., {2, 3, 4, 5}). The scaling factor may be any value (e.g., 1.5, 2, 2.5, etc.). For example, if the scaling factor is provided by RRC message and the value is set to 2, for μ=1, the value of N.sub.1_relaxed may be twice of the value of N, for PDSCH processing capability 1 (e.g., 8×2=16 symbols). The scaling factor may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities are supported. Whether the scaling factor is applied for the relaxed processing time or not is RRC configured. For example, for a UE that supports reduced UE processing capability (new capability) on a given cell, the processing time according to reduced UE processing capability (i.e., processing time derived by the scaling factor for the relaxed PDSCH decoding time N.sub.1_relaxed), may be applied if the high layer parameter processingRelaxedEnabled in PDSCH-ServingCellConfig is configured for the cell and/or set to enable and/or the high layer parameter processingScalingFactor is configured. Reduced capability UE may support both relaxed PDSCH processing capability and PDSCH processing capability 1 (and/or PDSCH processing capability 2). In a case that relaxed PDSCH processing capability is enabled and scaling factor is configured, provided and/or defined, the value of N.sub.1_relaxed may be the value of N.sub.1 for PDSCH processing capability 1 (or the value of N.sub.1 for PDSCH processing capability 2) times the scaling factor. A reduced capability UE may support relaxed PDSCH processing capability without support of PDSCH processing capability 1 (and/or PDSCH processing capability 2). In a case that relaxed PDSCH processing capability is enabled and scaling factor is configured/provided/defined, the value of N.sub.1_relaxed may be still based on the value of N.sub.1 defined, provided and/or configured for PDSCH processing capability 1 (or the value of N.sub.1 defined, provided and/or configured for PDSCH processing capability 2) times the scaling factor.

(194) In yet another example, the relaxed PDSCH decoding time N.sub.1_relaxed may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms). Namely, when new tables and/or values for the relaxed PDSCH decoding time N.sub.1_relaxed are provided, the unit of the values for N.sub.1_relaxed may be slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) instead of symbols. For example, N.sub.1_relaxed is 1 slot for μ=1 and N.sub.1_relaxed is 2 slots for μ=2. Whether the new tables and/or values for the relaxed PDSCH decoding time N.sub.1_relaxed in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) are applied for the relaxed processing time or not is RRC configured. For example, N.sub.1_relaxed in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) is applied if the high layer parameter processingRelaxedEnabled in PDSCH-ServingCellConfig is configured for the cell and/or set to enable. An example of PDSCH processing time for relaxed PDSCH processing capability is show in Table 6.

(195) TABLE-US-00022 TABLE 6 PDSCH decoding time N.sub.1, relaxed [slots] dmrs-AdditionalPosition = pos0 in DMRS-DownlinkConfig in both of dmrs-DownlinkForPDSCH-MappingTypeA, μ dmrs-DownlinkForPDSCH-MappingTypeB 0 1 1 2 2 3

(196) Relaxed UE PDSCH processing procedure time is also described herein. If the first uplink symbol of the PUCCH which carries the HARQ-ACK information, as defined by the assigned HARQ-ACK timing K.sub.1 and the PUCCH resource to be used and including the effect of the timing advance, starts no earlier than at symbol L.sub.1, where L.sub.1 is defined as the next uplink symbol with its CP starting T.sub.proc,1,relaxed after the end of the last symbol of the PDSCH carrying the TB being acknowledged, then the UE may provide a valid HARQ-ACK message. Otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH. The value of T.sub.proc,1,relaxed is used both in the case of normal and extended cyclic prefix. T.sub.proc,1,relaxed May be referred to as relaxed UE PDSCH processing time or relaxed UE PDSCH processing procedure time. The relaxed UE PDSCH processing time T.sub.proc,1,relaxed may be determined by relaxed PDSCH decoding time N.sub.1_relaxed, carrier aggregation, PDSCH mapping type, the number of PDSCH symbols allocated, and/or scheduled RB allocation. Examples of relaxed UE PDSCH processing time T.sub.proc,1,relaxed calculation are described in the following. In an example, calculation of the relaxed UE PDSCH processing time T.sub.proc,1,relaxed may use the same formula for UE processing capability 1 and/or UE processing capability 2. Namely, the relaxed UE PDSCH processing T.sub.proc,1,relaxed may be given by T.sub.proc,1,relaxed=

(N.sub.1,relaxed+d.sub.1,1,relaxed)(2048+144).Math.κ**2**.sup.−μ.Math.T.sub.C. N.sub.1_relaxed may be given by the relaxed PDSCH decoding time described above. The determination of d.sub.1,1,relaxed may follow the same procedure/method as d.sub.1,1.

(197) In yet another example, a separate rule, procedure and/or method may be used to determine d.sub.1,1,relaxed. In some examples, d.sub.1,1,relaxed may be determined by PDSCH mapping type, the number of PDSCH symbols allocated, the last symbol of PDSCH, the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), and/or the scheduled RB allocation. In some examples, d.sub.1,1,relaxed may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported.

(198) In yet another example, d.sub.1,1,relaxed may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) in a case that N.sub.1_relaxed is in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms). In addition, the formula for calculation of the relaxed UE PDSCH processing time T.sub.proc,1,relaxed may be modified to align with the unit. For example, if N.sub.1_relaxed and d.sub.1,1,relaxed are given in a unit of slot, the relaxed UE PDSCH processing time T.sub.proc,1,relaxed may be given by T.sub.proc,1,relaxed= (N.sub.1,relaxed+d.sub.1,1,relaxed).Math.14.Math.(2048+144).Math.κ2.sup.−‖.Math.T.sub.C. If N.sub.1_relaxed and d.sub.1,1,relaxed are given in a unit of sub-slot, the relaxed UE PDSCH processing time T.sub.proc,1,relaxed may be given by

T.sub.proc,1,relaxed=(*N*.sub.1,relaxed+*d*.sub.1,1,relaxed).Math.*N*.sub.subslot.Math.(2048+144).Math.κ2.sup.−μ.*Math.T*.sub.C,

where N.sub.subslot is the number of symbols in a sub-slot.

(199) In yet another example, an offset may be introduced for calculation of the relaxed UE PDSCH processing time T.sub.proc,1,relaxed. Namely, the relaxed UE PDSCH processing time T.sub.proc,1,relaxed may be given by *T*.sub.proc,1,relaxed=(*N*.sub.1,relaxed+*d*.sub.1,1,relaxed+*N*.sub.1,offset)(2048+144).Math.κ2.sup.−μ.*Math.T*.sub.C. N.sub.1,offset may be determined by numerology, PDSCH mapping type, the number of PDSCH symbols allocated, the last symbol of PDSCH, the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), and/or the scheduled RB allocation. N.sub.1,offset may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. The value of N.sub.1,offset may be fixed in the specification, or RRC configured. The value of N.sub.1,offset may be selected from a set of values (e.g., (2, 3, 4, 5)). The N.sub.1,offset may be any value (e.g., 1.5, 2, 2.5, etc.). N.sub.1,offset may be in a unit of symbol. N.sub.1,offset may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) in a case that N.sub.1_relaxed is in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms).

(200) In yet another example, an alternative relaxed UE PDSCH processing time d.sub.1,2,relaxed may be defined, provided and/or configured and UE may determine the value of relaxed UE PDSCH processing time from d.sub.1,2,relaxed and the value of calculated T.sub.proc,1,relaxed as above. For example,

(201)

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}} + N_{1,\text{offset}})\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right),$$

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}})\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right),$$

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}} + N_{1,\text{offset}})\ .\text{Math.}\ 14\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right),$$

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}})\ .\text{Math.}\ 14\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right),$$

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}})\ .\text{Math.}\ N_{\text{subslot}}\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right)\text{or}$$

$$T_{\text{proc},1} = \max\left((N_{1,\text{relaxed}} + d_{1,1,\text{relaxed}} + N_{1,\text{offset}})\ .\text{Math.}\ N_{\text{subslot}}\ .\text{Math.}\ (2048+144)\ .\text{Math.}\ \kappa 2^{-\mu}\ .\text{Math.}\ T_C,\ d_{1,2,\text{relaxed}}\right).$$

(202) In some examples, d.sub.1,2,relaxed may be determined by BWP switching time (e.g., if the scheduling DCI triggered a switch of BWP, d.sub.1,2,relaxed equals to the switching time, otherwise d.sub.1,2,relaxed=0), DMRS configurations (e.g., DMRS position, additional position, mapping type, whether the first symbol of the PDSCH allocation includes DM-RS only or not), PDSCH mapping type, the number of PDSCH symbols allocated, the last

symbol of PDSCH, the number of overlapping symbols of the scheduling PDCCH and the scheduled PDSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), the scheduled RB allocation. $d_{1,2,relaxed}$ may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported, e.g. $d_{1,2,relaxed}=0$ for Reduced UE capability 1 (high-end device) and $d_{1,2,relaxed}=4$ ms for Reduced UE capability 2 (low-end device, e.g., wearable).
(203) In yet another example, an explicit table may be introduced, provided and/or configured for determination of the relaxed UE PDSCH processing time $T_{proc,1,relaxed}$. The value of the relaxed UE PDSCH processing time $T_{proc,1,relaxed}$ in the table may be determined by numerology, PDSCH mapping type, and/or DMRS configurations (e.g., DMRS position, additional position, mapping type), the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. Examples of PDSCH processing time for relaxed PDSCH processing capability are shown is Table 7 and Table 8.
(204) TABLE-US-00023 TABLE 7 PDSCH processing time $T_{proc, 1, relaxed}$ [ms] Reduced UE capability 2 μ Reduced UE capability 1 (e.g., wearable) 0 1 2 1 0.75 1.5 2 0.5 1.25 3 0.5 1
(205) TABLE-US-00024 TABLE 8 μ PDSCH processing time $T_{proc, 1, relaxed}$ [ms] −2 2 −1 1.5 0 1.25 1 1 2 0.75
(206) In a case that $N_{1\_relaxed}$ and/or $d_{1,1,relaxed}$ may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms), the definition of relaxed UE PDSCH processing procedure time may be modified, updated and/or re-defined to align with the unit of $N_{1\_relaxed}$ and/or $d_{1,1,relaxed}$. For example, in a case that $N_{1\_relaxed}$ and/or $d_{1,1,relaxed}$ may be in a unit of slot (or sub-slot), if the first slot (or sub-slot) with uplink symbol of the PUCCH which carries the HARQ-ACK information, as defined by the assigned HARQ-ACK timing K_1 and the PUCCH resource to be used and including the effect of the timing advance, starts no earlier than at slot SL_1 (or sub-slot $SubL_1$), where SL_1 (or $SubL_1$) is defined as the next slot (or sub-slot) with uplink symbol starting $T_{proc,1,relaxed}$ after the end of the last slot (or sub-slot) of the PDSCH carrying the TB being acknowledged, then the UE may provide a valid HARQ-ACK message. Otherwise the UE may not provide a valid HARQ-ACK corresponding to the scheduled PDSCH. The value of $T_{proc,1,relaxed}$ may be used both in the case of normal and extended cyclic prefix. $T_{proc,1,relaxed}$ may be referred to as relaxed UE PDSCH processing time or relaxed UE PDSCH processing procedure time.
(207) UE PUSCH preparation procedure time is also described herein. If the first uplink symbol in the PUSCH allocation for a transport block, including the DM-RS, as defined by the slot offset K_2 and the start and length indicator SLIV of the scheduling DCI and including the effect of the timing advance, is no earlier than at symbol L_2, where L_2 is defined as the next uplink symbol with its CP starting $T_{proc,2}$ after the end of the reception of the last symbol of the PDCCH carrying the DCI scheduling the PUSCH, then the UE may transmit the transport block. Otherwise the UE may ignore the scheduling DCI. The value of $T_{proc,2}$ is used both in the case of normal and extended cyclic prefix. $T_{proc,2}$ may be referred to as UE PUSCH preparation procedure time.
(208) The UE PUSCH preparation procedure time $T_{proc,2}$ may be determined by PUSCH preparation time N_2 [symbols]. N_2 may be based on numerology μ for different UE processing capabilities (e.g., capability 1, 2 or new capability, reduced capability), where μ corresponds to the one of (μ_{DL}, μ_{UL}) resulting with the largest $T_{proc,2}$, where the μ_{DL} corresponds to the subcarrier spacing of the downlink with which the PDCCH carrying the DCI scheduling the PUSCH was transmitted and μ_{UL} corresponds to the subcarrier spacing of the uplink channel with which the PUSCH is to be transmitted. p may be the index of numerology and the subcarrier spacing is given by $\Delta f=2^{\mu}\cdot 15$ [kHz]. Examples of PUSCH preparation time for PUSCH timing capability 1 are shown in Table 9. Examples of PUSCH preparation time for PUSCH timing capability 2 are shown in Table 10.
(209) TABLE-US-00025 TABLE 9 μ PUSCH preparation time N_2 [symbols] 0 10 1 12 2 23 3 36
(210) TABLE-US-00026 TABLE 10 μ PUSCH preparation time N_2 [symbols] 0 5 1 5.5 2 11 for frequency range 1
(211) The UE PUSCH preparation procedure time $T_{proc,2}$ may also be determined by carrier aggregation, BWP switching time, DMRS configurations (e.g., DMRS position, additional position, and/or mapping type).
(212) For example, the UE PUSCH preparation procedure time $T_{proc,2}$ may be given by $T_{proc,2}=\max((N_2+d_{2,1})(2048+144)\cdot\kappa \mathbf{2}^{-\mu}\cdot T_C, d_{2,2})$. If the first symbol of the PUSCH allocation includes DM-RS only, then $d_{2,1}=0$, otherwise $d_{2,1}=1$. If the UE is configured with multiple active component carriers, the first uplink symbol in the PUSCH allocation further includes the effect of timing difference between component carriers. If the scheduling DCI triggered a switch of BWP, $d_{2,2}$ equals to the switching time, otherwise $d_{2,2}=0$.
(213) Whether to apply UE processing capability 2 or not may be RRC configured. For example, for a UE that supports capability 2 on a given cell, the processing time according to UE processing capability 2 is applied if the high layer parameter processingType2Enabled in PUSCH-ServingCellConfig is configured for the cell and set to enable.
(214) To support reduced capability NR devices, relaxed UE PUSCH preparation procedure time and/or reduced UE

processing capability (new capability) may be introduced. Definitions and/or methods for relaxed UE PUSCH preparation procedure time may be introduced described in the following.
(215) Relaxed PUSCH preparation time N.sub.2_relaxed may be introduced. N.sub.2_relaxed may be based on numerology μ for the reduced UE processing capability (new capability), where μ corresponds to the one of (μ.sub.DL, μ.sub.UL) (e.g., the one resulting with the largest processing/preparation time). For reduced UE capability, large subcarrier spacing may not be supported. Namely, μ may be selected from small values, e.g., 0, 1, 2. Subcarrier spacing less than 15 kHz may be supported (e.g., 7.5 kHz and 3.75 kHz, etc.). Namely, μ may be −1, or −2, etc. Relaxed PUSCH preparation time N.sub.2_relaxed may also be determined by DMRS configurations (e.g., DMRS position, additional position, and/or mapping type). DMRS configurations may be separately configured for reduced capability UE. DMRS configurations (e.g., DMRS position, additional position, mapping type), may be newly designed and/or introduced for reduced capability UE. The formula and/or methods to calculate the relaxed UE PUSCH preparation procedure time (by taking into account DMRS configuration) may be different from PUSCH timing capability 1 and PUSCH timing capability 2.
(216) In an example, a new table, which is different from the examples of PUSCH preparation time for PUSCH timing capability 1 and for PUSCH timing capability 2 shown in Table 9 and Table 10, may be introduced for the relaxed PUSCH preparation time N.sub.2_relaxed. The value of N.sub.2_relaxed [symbols] may be larger than the value of N.sub.2 for PUSCH timing capability 1 and for PUSCH timing capability 2. The number of rows in the new table may be less than the number of rows in the tables for PUSCH timing capability 1 and for PUSCH timing capability 2, since fewer numerologies may be supported for the relaxed processing/preparation time. The value of N.sub.2_relaxed may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. Whether the new table is applied for the relaxed processing time or not is RRC configured. For example, for a UE that supports reduced UE processing/timing capability (new capability) on a given cell, the processing/preparation time according to reduced UE processing capability, i.e., processing/preparation time determined by the new table for the relaxed PUSCH preparation time N.sub.2_relaxed is applied if the high layer parameter processingRelaxedEnabled in PUSCH-ServingCellConfig is configured for the cell and/or set to enable. Some examples of PUSCH preparation time for relaxed PUSCH preparation/processing/timing capability are shown in Table 11, Table 12 and Table 13. In Table 12, there are two reduced UE capabilities. One is reduced UE capability 1 for high-end reduced capability devices/services and the other is reduced UE capability 2 for low-end reduced capability devices/services. Each reduced UE capability has a set of PUSCH preparation time. If the high layer parameter RedCapType is provided and set as RedCap1, the first RedCap (Reduced UE capability 1) may be applied to the UE, i.e., the PUSCH preparation time N.sub.2_relaxed is given by the column of Reduced UE capability 1. If the high layer parameter RedCapType is provided and set as RedCap2, the second RedCap (Reduced UE capability 2) may be applied to the UE, i.e., the PUSCH preparation time N.sub.2_relaxed is given by the column of Reduced UE capability 2. If the high layer parameter processingRelaxedEnabled in PUSCH-ServingCellConfig is configured for the cell and/or set to enable and the high layer parameter RedCapType is not provided, the first RedCap (Reduced UE capability 1) may be applied to the UE, i.e., the PUSCH preparation time N.sub.2_relaxed is given by the column of Reduced UE capability 1. In yet another design, if the high layer parameter processingRelaxedEnabled in PUSCH-ServingCellConfig is configured for the cell and/or set to enable and the high layer parameter RedCapType is not provided, the second RedCap (Reduced UE capability 2) may be applied to the UE, i.e., the PUSCH preparation time N.sub.2_relaxed is given by the column of Reduced UE capability 2.
(217) TABLE-US-00027 TABLE 11 μ PUSCH preparation time N.sub.2.sub.—.sub.relaxed [symbols] 0 13 1 20 2 28 3 42
(218) TABLE-US-00028 TABLE 12 PUSCH preparation time N.sub.2.sub.—.sub.relaxed [symbols] Reduced UE Reduced UE capability 2 capability 1 (low-end device, μ (high-end device) e.g., wearable) 0 13 20 1 20 23 2 28 43 3 42 56
(219) TABLE-US-00029 TABLE 13 μ PUSCH preparation time N.sub.2.sub.—.sub.relaxed [symbols] −2 8 −1 10 0 17 1 20 2 28
In yet another example, a scaling factor may be introduced and/or configured for the relaxed processing/preparation time. The value of N.sub.2_relaxed may be the value of N.sub.2 for PUSCH timing capability 1 (or the value of N.sub.2 for PUSCH timing capability 2) times the scaling factor. The scaling factor may be fixed in the specification, or RRC configured. The value of scaling factor may be selected from a set of values (e.g. {2, 3, 4, 5}). The scaling factor may be any value (e.g., 1.5, 2, 2.5, etc.). For example, if the scaling factor is provided by RRC message and the value is set to 2, for μ=1, the value of N.sub.2_relaxed may be twice of the value of N.sub.2 for PUSCH timing capability 1 (e.g., 10×2=20 symbols). The scaling factor may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. Whether the scaling factor is applied for the relaxed processing/preparation time or not is RRC configured. For example, for a UE that supports reduced UE processing capability (new capability) on a given cell, the processing/preparation time according to reduced UE processing capability, i.e., processing/preparation time derived by the scaling factor for the relaxed PUSCH

preparation time N.sub.2_relaxed is applied if the high layer parameter processingRelaxedEnabled in PUSCH-ServingCellConfig is configured for the cell and/or set to enable and/or the high layer parameter processingScalingFactor is configured. Reduced capability UE may support both relaxed PUSCH processing/preparation/timing capability and PUSCH processing/preparation/timing capability 1 (and/or PUSCH processing/preparation/timing capability 2). In a case that relaxed PUSCH processing/preparation/timing capability is enabled and scaling factor is configured/provided/defined, the value of N.sub.2_relaxed may be the value of N.sub.2 for PUSCH processing/preparation/timing capability 1 (or the value of N.sub.2 for PUSCH processing/preparation/timing capability 2) times the scaling factor. Reduced capability UE may support relaxed PUSCH processing/preparation/timing capability without support of PUSCH processing/preparation/timing capability 1 (and/or PUSCH processing/preparation/timing capability 2). In a case that relaxed PUSCH processing/preparation/timing capability is enabled and scaling factor is configured/provided/defined, the value of N.sub.2_relaxed may be still based on the value of N.sub.2 defined/provided/configured for PUSCH processing/preparation/timing capability 1 (or the value of N.sub.2 defined/provided/configured for PUSCH processing/preparation/timing capability 2) times the scaling factor.
(220) In yet another example, the relaxed PUSCH preparation time N.sub.2_relaxed may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms). Namely, when new tables and/or values for the relaxed PUSCH preparation time N.sub.2_relaxed are provided, the unit of the values for N.sub.2_relaxed may be slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) instead of symbols. For example, N.sub.2_relaxed is 1 slot for μ=1 and N.sub.2_relaxed is 2 slots for μ=2. Whether the new tables and/or values for the relaxed PUSCH preparation time N.sub.2_relaxed in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) are applied for the relaxed processing/preparation time or not is RRC configured. For example, N.sub.2_relaxed in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) is applied if the high layer parameter processingRelaxedEnabled in PUSCH-ServingCellConfig is configured for the cell and/or set to enable. An example of PUSCH preparation time for relaxed PUSCH timing/processing/preparation capability is show in Table 14.
(221) TABLE-US-00030 TABLE 14 μ PUSCH preparation time N.sub.2.sub.—.sub.relaxed [slots] 0 1 1 2 2 3
(222) Relaxed UE PUSCH preparation procedure time is also described herein. If the first uplink symbol in the PUSCH allocation for a transport block, including the DM-RS, as defined by the slot offset K.sub.2 and the start and length indicator SLIV of the scheduling DCI and including the effect of the timing advance, is no earlier than at symbol L.sub.2, where L.sub.2 is defined as the next uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of the reception of the last symbol of the PDCCH carrying the DCI scheduling the PUSCH, then the UE may transmit the transport block. Otherwise the UE may ignore the scheduling DCI. The value of T.sub.proc,2,relaxed is used both in the case of normal and extended cyclic prefix. T.sub.proc,2,relaxed may be referred to as relaxed UE PUSCH preparation procedure time. The relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be determined by relaxed PUSCH preparation time N.sub.2_relaxed, numerology, carrier aggregation, BWP switching time, and/or DMRS configurations (e.g., DMRS position, additional position, mapping type).
(223) For example, calculation of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may use the same formula for UE processing capability 1 and/or UE processing capability 2. Namely, the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by
$$T_{proc,2}=\max((N_{2,relaxed}+d_{2,1,relaxed})(2048+144)\cdot\kappa 2^{-\mu}\cdot T_{C},d_{2,2,relaxed})$$
N.sub.2_relaxed may be given by the relaxed PUSCH preparation time described above. The determination of d.sub.2,1,relaxed and d.sub.2,2,relaxed may follow the same procedure/method as d.sub.2,1 and d.sub.2,2.
In yet another example, a separate rule, procedure, and/or method may be used to determine d.sub.2,1,relaxed. In some examples, d.sub.2,1,relaxed may be determined by DMRS configurations (e.g., DMRS position, additional position, mapping type, whether the first symbol of the PUSCH allocation includes DM-RS only or not), PUSCH mapping type, the number of PUSCH symbols allocated, the last symbol of PUSCH, the number of overlapping symbols of the scheduling PUCCH and the scheduled PUSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), and/or the scheduled RB allocation. In some examples, d.sub.2,1,relaxed may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported (e.g., d.sub.2,1,relaxed=1 for Reduced UE capability 1 (high-end device) and d.sub.2,1,relaxed=2 for Reduced UE capability 2 (low-end device, e.g., wearable)).
(224) In yet another example, a separate rule, procedure and/or method may be used to determine d.sub.2,2,relaxed. In some examples, d.sub.2,2,relaxed may be determined by BWP switching time (e.g., if the scheduling DCI triggered a switch of BWP, d.sub.2,2,relaxed equals to the switching time, otherwise d.sub.2,2,relaxed=0), DMRS configurations (e.g., DMRS position, additional position, mapping type, whether the first symbol of the PUSCH allocation includes DM-RS only or not), PUSCH mapping type, the number of PUSCH symbols allocated, the last symbol of PUSCH, the number of overlapping symbols of the scheduling PUCCH and the scheduled PUSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), and/or the scheduled RB allocation. In some examples, d.sub.2,2,relaxed may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported (e.g., d.sub.2,2,relaxed=0 for Reduced UE capability 1

(high-end device) and d.sub.2,2,relaxed=4 ms for Reduced UE capability 2 (low-end device, e.g., wearable)).
(225) In yet another example, d.sub.2,2,relaxed may not be used, defined and/or provided for the calculation of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed. BWP switching may not be supported by reduced UE capability, so d.sub.2,2,relaxed may be always 0 and/or d.sub.2,2,relaxed may not be used/defined/provided. If d.sub.2,2,relaxed is not used, defined and/or/provided, the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by
T.sub.proc,2=(*N*.sub.2,relaxed+*d*.sub.2,1,relaxed)(2048+144).Math.κ2.sup.−μ.*Math.T*.sub.C.
(226) In yet another example, d.sub.2,1,relaxed may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) in a case that N.sub.2_relaxed is in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms). In addition, the formula for calculation of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be modified to align with the unit. For example, if N.sub.2_relaxed and d.sub.2,1,relaxed are given in a unit of slot, the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by

(227) $T_{\text{proc},2} = \max\left(\begin{matrix}(N_{2,\text{relaxed}} + d_{2,1,\text{relaxed}}) \text{ .Math. } 14 \text{ .Math. } \\ (2048+144) \text{ .Math. } \kappa 2^{-\mu} \text{ .Math. } T_C, d_{2,2,\text{relaxed}}\end{matrix}\right).$

(228) If N.sub.2_relaxed and d.sub.2,1,relaxed are given in a unit of sub-slot, the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by

(229) $T_{\text{proc},2} = \max\left(\begin{matrix}(N_{2,\text{relaxed}} + d_{2,1,\text{relaxed}}) \text{ .Math. } N_{\text{subslot}} \text{ .Math. } \\ (2048+144) \text{ .Math. } \kappa 2^{-\mu} \text{ .Math. } T_C, d_{2,2,\text{relaxed}}\end{matrix}\right),$

where N.sub.subslot is the number of symbols in a sub-slot.
(230) In a case that N.sub.2_relaxed and/or d.sub.2,1,relaxed are in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms), d.sub.2,2,relaxed may not be used, defined and/or provided for the calculation of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed, or d.sub.2,2,relaxed may be always 0. For example, if N.sub.2_relaxed and/or d.sub.2,1,relaxed are given in a unit of slot, d.sub.2,2,relaxed may not be used/defined/provided and the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by
T.sub.proc,2=(*N*.sub.2,relaxed+*d*.sub.2,1,relaxed).Math.14.Math.(2048+144).Math.κ2.sup.−μ.*Math.T*.sub.C.
(231) In yet another example, an offset may be introduced for calculation of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed Namely, the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed may be given by
(232)

$T_{\text{proc},2} = \max\left(\begin{matrix}(N_{2,\text{relaxed}} + d_{2,1,\text{relaxed}}) + N_{2,\text{offset}}) \text{ .Math. } \\ (2048+144) \text{ .Math. } \kappa 2^{-\mu} \text{ .Math. } T_C, d_{2,2,\text{relaxed}}\end{matrix}\right) \text{or} T_{\text{proc},2} = \left(\begin{matrix}(N_{2,\text{relaxed}} + d_{2,1,\text{relaxed}} + N_{2,\text{offset}}) \\ (2048+144) \text{ .Math. } \kappa 2^{-\mu} \text{ .Math. } T_C \text{ .}\end{matrix}\right)$

N.sub.2,offset may be determined by numerology, BWP switching time (e.g., if the scheduling DCI triggered a switch of BWP, d.sub.2,offset may be determined by the switching time, otherwise d.sub.2,offset=0 or other pre-defined/configured value), DMRS configurations (e.g., DMRS position, additional position, mapping type, whether the first symbol of the PUSCH allocation includes DM-RS only or not), PUSCH mapping type, the number of PUSCH symbols allocated, the last symbol of PUSCH, the number of overlapping symbols of the scheduling PUCCH and the scheduled PUSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), and/or the scheduled RB allocation. N.sub.2,offset may be determined by the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. The value of N.sub.2,offset may be fixed in the specification, or RRC configured. The value of N.sub.2,offset may be selected from a set of values (e.g. {2, 3, 4, 5}). The N.sub.2,offset may be any value (e.g., 1.5, 2, 2.5, etc.). N.sub.2,offset may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) in a case that N.sub.2_relaxed is in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms). N.sub.2,offset may be in a unit of symbol. N.sub.2,offset may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms) in a case that N.sub.2_relaxed is in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms).
(233) In yet another example, an explicit table may be introduced, provided and/or configured for determination of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed. The value of the relaxed UE PUSCH preparation procedure time T.sub.proc,2,relaxed in the table may be determined by numerology, BWP switching time (e.g., if the scheduling DCI triggered a switch of BWP, T.sub.proc,2,relaxed may be determined by the switching time, Otherwise T.sub.proc,2,relaxed=2 ms or other pre-defined/configured value), DMRS configurations (e.g., DMRS position, additional position, mapping type, whether the first symbol of the PUSCH allocation includes DM-RS only or not), PUSCH mapping type, the number of PUSCH symbols allocated, the last symbol of PUSCH, the number of overlapping symbols of the scheduling PUCCH and the scheduled PUSCH, the CORESET (e.g., the start symbol of the CORESET, the number of symbols of the CORESET), the scheduled RB allocation, and/or the specific reduced UE capability in a case that multiple reduced UE capabilities may be supported. Examples of UE PUSCH preparation procedure time for relaxed PUSCH processing, timing and/or preparation capability are shown

in Table 15 and Table 16.

(234) TABLE-US-00031 TABLE 15 UE PUSCH preparation procedure time T.sub.proc, 2, relaxed [ms] Reduced UE Reduced UE capability 2 capability 1 (low-end devices, μ (high-end devices) e.g., wearable) 0 1 2 1 0.75 1.5 2 0.5 1.25 3 0.5 1

(235) TABLE-US-00032 TABLE 16 μ UE PUSCH preparation procedure time T.sub.proc, 2, relaxed [ms] −2 2 −1 1.5 0 1.25 1 1 2 0.75

(236) In a case that N.sub.2_relaxed and/or d.sub.2,1,relaxed may be in a unit of slot, sub-slot, mini-slot, subframe, frame or time (e.g., ms), the definition of relaxed UE PUSCH preparation procedure time may be modified, updated and/or re-defined to align with the unit of N.sub.1_relaxed and/or d.sub.1,1,relaxed. For example, in a case that N.sub.2_relaxed and/or d.sub.2,1,relaxed may be in a unit of slot (or sub-slot), if the first slot (or sub-slot) with uplink symbol in the PUSCH allocation for a transport block, including the DM-RS, as defined by the slot offset K.sub.2 and the start and length indicator SLIV of the scheduling DCI and including the effect of the timing advance, is no earlier than at slot SL.sub.2 (or sub-slot SubL.sub.2), where L.sub.2 (or SubL.sub.2) is defined as the next slot (or sub-slot) with uplink symbol with its CP starting T.sub.proc,2,relaxed after the end of the reception of the last slot (or sub-slot) with symbol of the PDCCH carrying the DCI scheduling the PUSCH, then the UE may transmit the transport block. Otherwise the UE may ignore the scheduling DCI. The value of T.sub.proc,2,relaxed may be used both in the case of normal and extended cyclic prefix. T.sub.proc,2,relaxed may be referred to as relaxed UE PUSCH preparation procedure time.

(237) The UE operations module **124** may provide information **148** to the one or more receivers **120**. For example, the UE operations module **124** may inform the receiver(s) **120** when to receive retransmissions.

(238) The UE operations module **124** may provide information **138** to the demodulator **114**. For example, the UE operations module **124** may inform the demodulator **114** of a modulation pattern anticipated for transmissions from the gNB **160**.

(239) The UE operations module **124** may provide information **136** to the decoder **108**. For example, the UE operations module **124** may inform the decoder **108** of an anticipated encoding for transmissions from the gNB **160**.

(240) The UE operations module **124** may provide information **142** to the encoder **150**. The information **142** may include data to be encoded and/or instructions for encoding. For example, the UE operations module **124** may instruct the encoder **150** to encode transmission data **146** and/or other information **142**. The other information **142** may include PDSCH HARQ-ACK information.

(241) The encoder **150** may encode transmission data **146** and/or other information **142** provided by the UE operations module **124**. For example, encoding the data **146** and/or other information **142** may involve error detection and/or correction coding, mapping data to space, time and/or frequency resources for transmission, multiplexing, etc. The encoder **150** may provide encoded data **152** to the modulator **154**.

(242) The UE operations module **124** may provide information **144** to the modulator **154**. For example, the UE operations module **124** may inform the modulator **154** of a modulation type (e.g., constellation mapping) to be used for transmissions to the gNB **160**. The modulator **154** may modulate the encoded data **152** to provide one or more modulated signals **156** to the one or more transmitters **158**.

(243) The UE operations module **124** may provide information **140** to the one or more transmitters **158**. This information **140** may include instructions for the one or more transmitters **158**. For example, the UE operations module **124** may instruct the one or more transmitters **158** when to transmit a signal to the gNB **160**. For instance, the one or more transmitters **158** may transmit during a UL subframe. The one or more transmitters **158** may upconvert and transmit the modulated signal(s) **156** to one or more gNBs **160**.

(244) Each of the one or more gNBs **160** may include one or more transceivers **176**, one or more demodulators **172**, one or more decoders **166**, one or more encoders **109**, one or more modulators **113**, a data buffer **162** and a gNB operations module **182**. For example, one or more reception and/or transmission paths may be implemented in a gNB **160**. For convenience, only a single transceiver **176**, decoder **166**, demodulator **172**, encoder **109** and modulator **113** are illustrated in the gNB **160**, though multiple parallel elements (e.g., transceivers **176**, decoders **166**, demodulators **172**, encoders **109** and modulators **113**) may be implemented.

(245) The transceiver **176** may include one or more receivers **178** and one or more transmitters **117**. The one or more receivers **178** may receive signals from the UE **102** using one or more antennas **180***a-n*. For example, the receiver **178** may receive and downconvert signals to produce one or more received signals **174**. The one or more received signals **174** may be provided to a demodulator **172**. The one or more transmitters **117** may transmit signals to the UE **102** using one or more antennas **180***a-n*. For example, the one or more transmitters **117** may upconvert and transmit one or more modulated signals **115**.

(246) The demodulator **172** may demodulate the one or more received signals **174** to produce one or more demodulated signals **170**. The one or more demodulated signals **170** may be provided to the decoder **166**. The gNB **160** may use the decoder **166** to decode signals. The decoder **166** may produce one or more decoded signals **164**, **168**. For example, a first eNB-decoded signal **164** may comprise received payload data, which may be stored in a data buffer **162**. A second eNB-decoded signal **168** may comprise overhead data and/or control data. For example,

the second eNB-decoded signal **168** may provide data (e.g., PDSCH HARQ-ACK information) that may be used by the gNB operations module **182** to perform one or more operations.

(247) In general, the gNB operations module **182** may enable the gNB **160** to communicate with the one or more UEs **102**. The gNB operations module **182** may include a gNB scheduling module **194**. The gNB scheduling module **194** may perform operations for resource allocation of enhanced uplink transmissions as described herein.

(248) The gNB operations module **182** may provide information **188** to the demodulator **172**. For example, the gNB operations module **182** may inform the demodulator **172** of a modulation pattern anticipated for transmissions from the UE(s) **102**.

(249) The gNB operations module **182** may provide information **186** to the decoder **166**. For example, the gNB operations module **182** may inform the decoder **166** of an anticipated encoding for transmissions from the UE(s) **102**.

(250) The gNB operations module **182** may provide information **101** to the encoder **109**. The information **101** may include data to be encoded and/or instructions for encoding. For example, the gNB operations module **182** may instruct the encoder **109** to encode information **101**, including transmission data **105**.

(251) The encoder **109** may encode transmission data **105** and/or other information included in the information **101** provided by the gNB operations module **182**. For example, encoding the data **105** and/or other information included in the information **101** may involve error detection and/or correction coding, mapping data to space, time and/or frequency resources for transmission, multiplexing, etc. The encoder **109** may provide encoded data **111** to the modulator **113**. The transmission data **105** may include network data to be relayed to the UE **102**.

(252) The gNB operations module **182** may provide information **103** to the modulator **113**. This information **103** may include instructions for the modulator **113**. For example, the gNB operations module **182** may inform the modulator **113** of a modulation type (e.g., constellation mapping) to be used for transmissions to the UE(s) **102**. The modulator **113** may modulate the encoded data **111** to provide one or more modulated signals **115** to the one or more transmitters **117**.

(253) The gNB operations module **182** may provide information **192** to the one or more transmitters **117**. This information **192** may include instructions for the one or more transmitters **117**. For example, the gNB operations module **182** may instruct the one or more transmitters **117** when to (or when not to) transmit a signal to the UE(s) **102**. The one or more transmitters **117** may upconvert and transmit the modulated signal(s) **115** to one or more UEs **102**.

(254) It should be noted that a DL subframe may be transmitted from the gNB **160** to one or more UEs **102** and that a UL subframe may be transmitted from one or more UEs **102** to the gNB **160**. Furthermore, both the gNB **160** and the one or more UEs **102** may transmit data in a standard special subframe.

(255) It should also be noted that one or more of the elements or parts thereof included in the eNB(s) **160** and UE(s) **102** may be implemented in hardware. For example, one or more of these elements or parts thereof may be implemented as a chip, circuitry or hardware components, etc. It should also be noted that one or more of the functions or methods described herein may be implemented in and/or performed using hardware. For example, one or more of the methods described herein may be implemented in and/or realized using a chipset, an application-specific integrated circuit (ASIC), a large-scale integrated circuit (LSI) or integrated circuit, etc.

(256) URLLC may coexist with other services (e.g., eMBB). Due to the latency requirement, URLLC may have a highest priority in some approaches. Some examples of URLLC coexistence with other services are given herein (e.g., in one or more of the following Figure descriptions).

(257) FIG. **2** is a diagram illustrating one example of a resource grid for the downlink. The resource grid illustrated in FIG. **2** may be utilized in some implementations of the systems and methods disclosed herein. More detail regarding the resource grid is given in connection with FIG. **1**.

(258) In FIG. **2**, one downlink subframe **269** may include two downlink slots **283**. N.sup.DL.sub.RB is downlink bandwidth configuration of the serving cell, expressed in multiples of N.sup.RB.sub.sc, where N.sup.RB.sub.sc is a resource block **289** size in the frequency domain expressed as a number of subcarriers, and N.sup.DL.sub.symb is the number of OFDM symbols **287** in a downlink slot **283**. A resource block **289** may include a number of resource elements (RE) **291**.

(259) For a PCell, N.sup.DL.sub.RB is broadcast as a part of system information. For a SCell (including a Licensed Assisted Access (LAA) SCell), N.sup.DL.sub.RB is configured by an RRC message dedicated to a UE **102**. For PDSCH mapping, the available RE **291** may be the RE **291** whose index 1 fulfils 1≥1.sub.data,start and/or 1.sub.data,end≥1 in a subframe.

(260) In the downlink, the OFDM access scheme with cyclic prefix (CP) may be employed, which may be also referred to as CP-OFDM. In the downlink, PDCCH, enhanced PDCCH (EPDCCH), PDSCH and the like may be transmitted. A downlink radio frame may include multiple pairs of downlink resource blocks (RBs) which is also referred to as physical resource blocks (PRBs). The downlink RB pair is a unit for assigning downlink radio resources, defined by a predetermined bandwidth (RB bandwidth) and a time slot. The downlink RB pair includes two downlink RBs that are continuous in the time domain.

(261) The downlink RB includes twelve sub-carriers in frequency domain and seven (for normal CP) or six (for extended CP) OFDM symbols in time domain. A region defined by one sub-carrier in frequency domain and one OFDM symbol in time domain is referred to as a resource element (RE) and is uniquely identified by the index pair (k,l) in a slot, where k and l are indices in the frequency and time domains, respectively. While downlink subframes in one component carrier (CC) are discussed herein, downlink subframes are defined for each CC and downlink subframes are substantially in synchronization with each other among CCs.
(262) FIG. **3** is a diagram illustrating one example of a resource grid for the uplink. The resource grid illustrated in FIG. **3** may be utilized in some implementations of the systems and methods disclosed herein. More detail regarding the resource grid is given in connection with FIG. **1**.
(263) In FIG. **3**, one uplink subframe **369** may include two uplink slots **383**. N.sup.UL.sub.RB is uplink bandwidth configuration of the serving cell, expressed in multiples of N.sup.RB.sub.sc, where N.sup.RB.sub.sc is a resource block **389** size in the frequency domain expressed as a number of subcarriers, and N.sup.UL.sub.symb is the number of SC-FDMA symbols **393** in an uplink slot **383**. A resource block **389** may include a number of resource elements (RE) **391**.
(264) For a PCell, N.sup.UL.sub.RB is broadcast as a part of system information. For a SCell (including an LAA SCell), N.sup.UL.sub.RB is configured by an RRC message dedicated to a UE **102**.
(265) In the uplink, in addition to CP-OFDM, a Single-Carrier Frequency Division Multiple Access (SC-FDMA) access scheme may be employed, which is also referred to as Discrete Fourier Transform-Spreading OFDM (DFT-S-OFDM). In the uplink, PUCCH, PUSCH, PRACH and the like may be transmitted. An uplink radio frame may include multiple pairs of uplink resource blocks. The uplink RB pair is a unit for assigning uplink radio resources, defined by a predetermined bandwidth (RB bandwidth) and a time slot. The uplink RB pair includes two uplink RBs that are continuous in the time domain.
(266) The uplink RB may include twelve sub-carriers in frequency domain and seven (for normal CP) or six (for extended CP) OFDM and/or DFT-S-OFDM symbols in time domain. A region defined by one sub-carrier in the frequency domain and one OFDM and/or DFT-S-OFDM symbol in the time domain is referred to as a RE and is uniquely identified by the index pair (k,l) in a slot, where k and l are indices in the frequency and time domains respectively. While uplink subframes in one component carrier (CC) are discussed herein, uplink subframes are defined for each CC.
(267) FIG. **4** shows examples of several numerologies **401**. The numerology #1 **401***a* may be a basic numerology (e.g., a reference numerology). For example, a RE **495***a* of the basic numerology **401***a* may be defined with subcarrier spacing **405***a* of 15 kHz in frequency domain and 2048 Ts+CP length (e.g., 160 Ts or 144 Ts) in time domain (i.e., symbol length #1 **403***a*), where Ts denotes a baseband sampling time unit defined as 1/(15000*2048) seconds. For the i-th numerology, the subcarrier spacing **405** may be equal to 15*2.sup.i and the effective OFDM symbol length 2048*2.sup.−i*Ts. It may cause the symbol length is 2048*2.sup.i*Ts+CP length (e.g., 160*2.sup.−i*Ts or 144*2.sup.−i*Ts). In other words, the subcarrier spacing of the i+1-th numerology is a double of the one for the i-th numerology, and the symbol length of the i+1-th numerology is a half of the one for the i-th numerology. FIG. **4** shows four numerologies, but the system may support another number of numerologies. Furthermore, the system does not have to support all of the 0-th to the I-th numerologies, i=0, 1, . . . , 1.
(268) For example, the first UL transmission on the first SPS resource as above mentioned may be performed only on the numerology #1 (e.g., a subcarrier spacing of 15 kHz). In some examples, the UE **102** may acquire (detect) the numerology #1 based on a synchronization signal. Also, the UE **102** may receive a dedicated RRC signal including information (e.g., a handover command) configuring the numerology #1. The dedicated RRC signal may be a UE-specific signal. In some examples, the first UL transmission on the first SPS resource may be performed on the numerology #1, the numerology #2 (a subcarrier spacing of 30 kHz), and/or the numerology #3 (a subcarrier spacing of 60 kHz).
(269) Also, the second UL transmission on the second SPS resource as above mentioned may be performed only on the numerology #3. In some examples, the UE **102** may receive System Information (e.g., Master Information Block (MIB) and/or System Information Block (SIB)) including information configuring the numerology #2 and/or the numerology #3.
(270) Also, the UE **102** may receive the dedicated RRC signal including information (e.g., the handover command) configuring the numerology #2 and/or the numerology #3. The System Information (e.g., MIB) may be transmitted on BCH (Broadcast Channel) and/or the dedicated RRC signal. The System Information (e.g., SIB) may contain information relevant when evaluating if a UE **102** is allowed to access a cell and/or defines the scheduling of other system information. The System Information (SIB) may contain radio resource configuration information that is common for multiple UEs **102**. For instance, the dedicated RRC signal may include each of multiple numerology configurations (the first numerology, the second numerology, and/or the third numerology) for each of UL transmissions (e.g., each of UL-SCH transmissions, each of PUSCH transmissions). Also, the dedicated RRC signal may include each of multiple numerology configurations (the first numerology, the second numerology, and/or the third numerology) for each of DL transmissions (each of PDCCH transmissions).

(271) FIG. **5** shows examples of subframe structures for the numerologies **501** that are shown in FIG. **4**. Given that a slot **283** includes N.sup.DL.sub.symb (or N.sup.UL.sub.symb)=7 symbols, the slot length of the i+1-th numerology **501** is a half of the one for the i-th numerology **501**, and eventually the number of slots **283** in a subframe (i.e., 1 ms) becomes double. It may be noted that a radio frame may include 10 subframes, and the radio frame length may be equal to 10 ms.
(272) FIG. **6** shows examples of slots **683** and sub-slots **607**. If a sub-slot **607** is not configured by higher layer, the UE **102** and the eNB and/or gNB **160** may only use a slot **683** as a scheduling unit. More specifically, a given transport block may be allocated to a slot **683**. If the sub-slot **607** is configured by higher layer, the UE **102** and the eNB and/or gNB **160** may use the sub-slot **607** as well as the slot **683**. The subslot **607** may include one or more OFDM symbols. The maximum number of OFDM symbols that constitute the sub-slot **607** may be N.sup.DL.sub.symb−1 (or N.sup.UL.sub.symb−1). The sub-slot length may be configured by higher layer signaling. Alternatively, the sub-slot length may be indicated by a physical layer control channel (e.g., by DCI format).
(273) The sub-slot **607** may start at any symbol within a slot **683** unless it collides with a control channel. There could be restrictions of mini-slot length based on restrictions on starting position. For example, the sub-slot **607** with the length of N.sup.DL.sub.symb−1 (or N.sup.UL.sub.symb−1) may start at the second symbol in a slot **683**. The starting position of a sub-slot **607** may be indicated by a physical layer control channel (e.g., by DCI format). Alternatively, the starting position of a sub-slot **607** may be derived from information (e.g., search space index, blind decoding candidate index, frequency and/or time resource indices, PRB index, a control channel element index, control channel element aggregation level, an antenna port index, etc.) of the physical layer control channel which schedules the data in the concerned sub-slot **607**.
(274) In cases when the sub-slot **607** is configured, a given transport block may be allocated to either a slot **683**, a sub-slot **607**, aggregated sub-slots **607** or aggregated sub-slot(s) **607** and slot **683**. This unit may also be a unit for HARQ-ACK bit generation.
(275) FIG. **7** shows examples of scheduling timelines **709**. For a normal DL scheduling timeline **709***a*, DL control channels are mapped the initial part of a slot **783***a*. The DL control channels **711** schedule DL shared channels **713***a* in the same slot **783***a*. HARQ-ACKs for the DL shared channels **713***a* (i.e., HARQ-ACKs each of which indicates whether or not transport block in each DL shared channel **713***a* is detected successfully) are reported via UL control channels **715***a* in a later slot **783***b*. In this instance, a given slot **783** may contain either one of DL transmission and UL transmission.
(276) For a normal UL scheduling timeline **709***b*, DL control channels **711***b* are mapped the initial part of a slot **783***c*. The DL control channels **711***b* schedule UL shared channels **717***a* in a later slot **783***d*. For these cases, the association timing (time shift) between the DL slot **783***c* and the UL slot **783***d* may be fixed or configured by higher layer signaling. Alternatively, it may be indicated by a physical layer control channel (e.g., the DL assignment DCI format, the UL grant DCI format, or another DCI format such as UE-common signaling DCI format which may be monitored in common search space).
(277) For a self-contained base DL scheduling timeline **709***c*, DL control channels **711***c* are mapped to the initial part of a slot **783***e*. The DL control channels **711***c* schedule DL shared channels **713***b* in the same slot **783***e*. HARQ-ACKs for the DL shared channels **713***b* are reported in UL control channels **715***b*, which are mapped at the ending part of the slot **783***e*.
(278) For a self-contained base UL scheduling timeline **709***d*, DL control channels **711***d* are mapped to the initial part of a slot **783***f*. The DL control channels **711***d* schedule UL shared channels **717***b* in the same slot **783***f*. For these cases, the slot **783***f* may contain DL and UL portions, and there may be a guard period between the DL and UL transmissions.
(279) The use of a self-contained slot may be upon a configuration of self-contained slot. Alternatively, the use of a self-contained slot may be upon a configuration of the subslot. Yet alternatively, the use of a self-contained slot may be upon a configuration of shortened physical channel (e.g., PDSCH, PUSCH, PUCCH, etc.).
(280) FIG. **8** shows examples of DL control channel monitoring regions. One or more sets of PRB(s) may be configured for DL control channel monitoring. In other words, a control resource set is, in the frequency domain, a set of PRBs within which the UE **102** attempts to blindly decode downlink control information, where the PRBs may or may not be frequency contiguous, a UE **102** may have one or more control resource sets, and one DCI message may be located within one control resource set. In the frequency-domain, a PRB is the resource unit size (which may or may not include Demodulation reference signals (DMRS)) for a control channel. A DL shared channel may start at a later OFDM symbol than the one(s) which carries the detected DL control channel. Alternatively, the DL shared channel may start at (or earlier than) an OFDM symbol than the last OFDM symbol which carries the detected DL control channel. In other words, dynamic reuse of at least part of resources in the control resource sets for data for the same or a different UE **102**, at least in the frequency domain may be supported.
(281) FIG. **9** shows examples of DL control channel which includes more than one control channel elements. When the control resource set spans multiple OFDM symbols, a control channel candidate may be mapped to multiple OFDM symbols or may be mapped to a single OFDM symbol. One DL control channel element may be mapped on

REs defined by a single PRB and a single OFDM symbol. If more than one DL control channel elements are used for a single DL control channel transmission, DL control channel element aggregation may be performed.
(282) The number of aggregated DL control channel elements is referred to as DL control channel element aggregation level. The DL control channel element aggregation level may be 1 or 2 to the power of an integer. The gNB **160** may inform a UE **102** of which control channel candidates are mapped to each subset of OFDM symbols in the control resource set. If one DL control channel is mapped to a single OFDM symbol and does not span multiple OFDM symbols, the DL control channel element aggregation is performed within an OFDM symbol, for instance multiple DL control channel elements within an OFDM symbol are aggregated. Otherwise, DL control channel elements in different OFDM symbols can be aggregated.
(283) FIG. **10** shows examples of UL control channel structures. UL control channel may be mapped on REs which are defined a PRB and a slot in frequency and time domains, respectively. This UL control channel may be referred to as a long format (or just the 1st format). UL control channels may be mapped on REs on a limited OFDM symbols in time domain. This may be referred to as a short format (or just the 2nd format). The UL control channels with a short format may be mapped on REs within a single PRB. Alternatively, the UL control channels with a short format may be mapped on REs within multiple PRBs. For example, interlaced mapping may be applied, for instance the UL control channel may be mapped to every N PRBs (e.g., 5 or 10) within a system bandwidth.
(284) FIG. **11** is a block diagram illustrating one implementation of a gNB **1160**. The gNB **1160** may include a higher layer processor **1123**, a DL transmitter **1125**, a UL receiver **1133**, and one or more antenna **1131**. The DL transmitter **1125** may include a PDCCH transmitter **1127** and a PDSCH transmitter **1129**. The UL receiver **1133** may include a PUCCH receiver **1135** and a PUSCH receiver **1137**.
(285) The higher layer processor **1123** may manage physical layer's behaviors (the DL transmitter's and the UL receiver's behaviors) and provide higher layer parameters to the physical layer. The higher layer processor **1123** may obtain transport blocks from the physical layer. The higher layer processor **1123** may send and/or acquire higher layer messages such as an RRC message and MAC message to and/or from a UE's higher layer. The higher layer processor **1123** may provide the PDSCH transmitter transport blocks and provide the PDCCH transmitter transmission parameters related to the transport blocks.
(286) The DL transmitter **1125** may multiplex downlink physical channels and downlink physical signals (including reservation signal) and transmit them via transmission antennas **1131**. The UL receiver **1133** may receive multiplexed uplink physical channels and uplink physical signals via receiving antennas **1131** and de-multiplex them. The PUCCH receiver **1135** may provide the higher layer processor **1123** UCI. The PUSCH receiver **1137** may provide the higher layer processor **1123** received transport blocks.
(287) FIG. **12** is a block diagram illustrating one implementation of a UE **1202**. The UE **1202** may include a higher layer processor **1223**, a UL transmitter **1251**, a DL receiver **1243**, and one or more antenna **1231**. The UL transmitter **1251** may include a PUCCH transmitter **1253** and a PUSCH transmitter **1255**. The DL receiver **1243** may include a PDCCH receiver **1245** and a PDSCH receiver **1247**.
(288) The higher layer processor **1223** may manage physical layer's behaviors (the UL transmitter's and the DL receiver's behaviors) and provide higher layer parameters to the physical layer. The higher layer processor **1223** may obtain transport blocks from the physical layer. The higher layer processor **1223** may send and/or acquire higher layer messages such as an RRC message and MAC message to and/or from a UE's higher layer. The higher layer processor **1223** may provide the PUSCH transmitter transport blocks and provide the PUCCH transmitter **1253** UCI.
(289) The DL receiver **1243** may receive multiplexed downlink physical channels and downlink physical signals via receiving antennas **1231** and de-multiplex them. The PDCCH receiver **1245** may provide the higher layer processor **1223** DCI. The PDSCH receiver **1247** may provide the higher layer processor **1223** received transport blocks.
(290) It should be noted that names of physical channels described herein are examples. The other names such as “NRPDCCH, NRPDSCH, NRPUCCH and NRPUSCH”, “new Generation-(G)PDCCH, GPDSCH, GPUCCH and GPUSCH” or the like can be used.
(291) FIG. **13** illustrates various components that may be utilized in a UE **1302**. The UE **1302** described in connection with FIG. **13** may be implemented in accordance with the UE **102** described in connection with FIG. **1**. The UE **1302** includes a processor **1303** that controls operation of the UE **1302**. The processor **1303** may also be referred to as a central processing unit (CPU). Memory **1305**, which may include read-only memory (ROM), random access memory (RAM), a combination of the two or any type of device that may store information, provides instructions **1307***a* and data **1309***a* to the processor **1303**. A portion of the memory **1305** may also include non-volatile random-access memory (NVRAM). Instructions **1307***b* and data **1309***b* may also reside in the processor **1303**. Instructions **1307***b* and/or data **1309***b* loaded into the processor **1303** may also include instructions **1307***a* and/or data **1309***a* from memory **1305** that were loaded for execution or processing by the processor **1303**. The instructions **1307***b* may be executed by the processor **1303** to implement the methods described above.
(292) The UE **1302** may also include a housing that contains one or more transmitters **1358** and one or more receivers **1320** to allow transmission and reception of data. The transmitter(s) **1358** and receiver(s) **1320** may be combined into one or more transceivers **1318**. One or more antennas **1322***a-n* are attached to the housing and

electrically coupled to the transceiver **1318**.
(293) The various components of the UE **1302** are coupled together by a bus system **1311**, which may include a power bus, a control signal bus and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in FIG. **13** as the bus system **1311**. The UE **1302** may also include a digital signal processor (DSP) **1313** for use in processing signals. The UE **1302** may also include a communications interface **1315** that provides user access to the functions of the UE **1302**. The UE **1302** illustrated in FIG. **13** is a functional block diagram rather than a listing of specific components.
(294) FIG. **14** illustrates various components that may be utilized in a gNB **1460**. The gNB **1460** described in connection with FIG. **14** may be implemented in accordance with the gNB **160** described in connection with FIG. **1**. The gNB **1460** includes a processor **1403** that controls operation of the gNB **1460**. The processor **1403** may also be referred to as a central processing unit (CPU). Memory **1405**, which may include read-only memory (ROM), random access memory (RAM), a combination of the two or any type of device that may store information, provides instructions **1407***a* and data **1409***a* to the processor **1403**. A portion of the memory **1405** may also include nonvolatile random-access memory (NVRAM). Instructions **1407***b* and data **1409***b* may also reside in the processor **1403**. Instructions **1407***b* and/or data **1409***b* loaded into the processor **1403** may also include instructions **1407***a* and/or data **1409***a* from memory **1405** that were loaded for execution or processing by the processor **1403**. The instructions **1407***b* may be executed by the processor **1403** to implement the methods described above.
(295) The gNB **1460** may also include a housing that contains one or more transmitters **1417** and one or more receivers **1478** to allow transmission and reception of data. The transmitter(s) **1417** and receiver(s) **1478** may be combined into one or more transceivers **1476**. One or more antennas **1480***a-n* are attached to the housing and electrically coupled to the transceiver **1476**.
(296) The various components of the gNB **1460** are coupled together by a bus system **1411**, which may include a power bus, a control signal bus and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in FIG. **14** as the bus system **1411**. The gNB **1460** may also include a digital signal processor (DSP) **1413** for use in processing signals. The gNB **1460** may also include a communications interface **1415** that provides user access to the functions of the gNB **1460**. The gNB **1460** illustrated in FIG. **14** is a functional block diagram rather than a listing of specific components.
(297) FIG. **15** is a block diagram illustrating one implementation of a UE **1502** in which systems and methods for relaxed uplink processing time may be implemented. The UE **1502** includes transmit means **1558**, receive means **1520** and control means **1524**. The transmit means **1558**, receive means **1520** and control means **1524** may be configured to perform one or more of the functions described in connection with FIG. **1** above. FIG. **13** above illustrates one example of a concrete apparatus structure of FIG. **15**. Other various structures may be implemented to realize one or more of the functions of FIG. **1**. For example, a DSP may be realized by software.
(298) FIG. **16** is a block diagram illustrating one implementation of a gNB **1660** in which systems and methods for relaxed uplink processing time may be implemented. The gNB **1660** includes transmit means **1623**, receive means **1678** and control means **1682**. The transmit means **1623**, receive means **1678** and control means **1682** may be configured to perform one or more of the functions described in connection with FIG. **1** above. FIG. **14** above illustrates one example of a concrete apparatus structure of FIG. **16**. Other various structures may be implemented to realize one or more of the functions of FIG. **1**. For example, a DSP may be realized by software.
(299) FIG. **17** is a flow diagram illustrating a method **1700** by a user equipment (UE) **102**. The UE **102** may receive **1702** a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The UE **102** may receive **1704** an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission. The UE **102** may receive **1706** an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time. The UE **102** may receive **1708** an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time. The UE **102** may transmit **1710**, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X. The symbol X may be defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH. T.sub.proc,2,relaxed May be determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time. FIG. **18** is a flow diagram illustrating a method **1800** by a base station (gNB) **160**. The gNB **160** may transmit **1802** a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The gNB **160** may transmit **1804** an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission. The gNB **160** may transmit **1806** an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time. The gNB **160** may transmit **1808** an RRC message comprising fourth information used for indicating an offset for reduced UE

PUSCH preparation time. The gNB **160** may receive **1810**, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X. The symbol X may be defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH. T.sub.proc,2,relaxed may be determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time. FIG. **19** is a flow diagram illustrating a method **1900** by a user equipment (UE) **102**. The UE **102** may receive **1902** a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The UE **102** may receive **1904** an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission. The UE **102** may transmit **1906**, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X. The slot or sub-slot X may be defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH. T.sub.proc,2,relaxed is determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot.

(300) FIG. **20** is a flow diagram illustrating a method **2000** by a base station (gNB) **160**. The gNB **160** may transmit **2002** a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities. The gNB **160** may transmit **2004** an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission. The gNB **160** may receive **2006**, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at slot or sub-slot X. The slot or sub-slot X may be defined as the next slot or sub-slot with uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed after the end of the reception of the last slot or sub-slot with symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH. T.sub.proc,2,relaxed may be determined by the first information, the second information, and a predefined table(s) including a set of UE PUSCH preparation time in a unit of slot or sub-slot. The term "computer-readable medium" refers to any available medium that can be accessed by a computer or a processor. The term "computer-readable medium," as used herein, may denote a computer- and/or processor-readable medium that is non-transitory and tangible. By way of example, and not limitation, a computer-readable or processor-readable medium may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer or processor. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers.

(301) It should be noted that one or more of the methods described herein may be implemented in and/or performed using hardware. For example, one or more of the methods described herein may be implemented in and/or realized using a chipset, an application-specific integrated circuit (ASIC), a large-scale integrated circuit (LSI) or integrated circuit, etc.

(302) Each of the methods disclosed herein comprises one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another and/or combined into a single step without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

(303) It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods, and apparatus described herein without departing from the scope of the claims.

(304) A program running on the gNB **160** or the UE **102** according to the described systems and methods is a program (a program for causing a computer to operate) that controls a CPU and the like in such a manner as to realize the function according to the described systems and methods. Then, the information that is handled in these apparatuses is temporarily stored in a RAM while being processed. Thereafter, the information is stored in various ROMs or HDDs, and whenever necessary, is read by the CPU to be modified or written. As a recording medium on which the program is stored, among a semiconductor (for example, a ROM, a nonvolatile memory card, and the like), an optical storage medium (for example, a DVD, a MO, a MD, a CD, a BD, and the like), a magnetic storage medium (for example, a magnetic tape, a flexible disk, and the like), and the like, any one may be possible. Furthermore, in some cases, the function according to the described systems and methods described above is realized

by running the loaded program, and in addition, the function according to the described systems and methods is realized in conjunction with an operating system or other application programs, based on an instruction from the program.
(305) Furthermore, in a case where the programs are available on the market, the program stored on a portable recording medium can be distributed or the program can be transmitted to a server computer that connects through a network such as the Internet. In this case, a storage device in the server computer also is included. Furthermore, some or all of the gNB **160** and the UE **102** according to the systems and methods described above may be realized as an LSI that is a typical integrated circuit. Each functional block of the gNB **160** and the UE **102** may be individually built into a chip, and some or all functional blocks may be integrated into a chip. Furthermore, a technique of the integrated circuit is not limited to the LSI, and an integrated circuit for the functional block may be realized with a dedicated circuit or a general-purpose processor. Furthermore, if with advances in a semiconductor technology, a technology of an integrated circuit that substitutes for the LSI appears, it is also possible to use an integrated circuit to which the technology applies.
(306) Moreover, each functional block or various features of the base station device and the terminal device used in each of the aforementioned implementations may be implemented or executed by a circuitry, which is typically an integrated circuit or a plurality of integrated circuits. The circuitry designed to execute the functions described in the present specification may comprise a general-purpose processor, a digital signal processor (DSP), an application specific or general application integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic devices, discrete gates or transistor logic, or a discrete hardware component, or a combination thereof. The general-purpose processor may be a microprocessor, or alternatively, the processor may be a conventional processor, a controller, a microcontroller or a state machine. The general-purpose processor or each circuit described above may be configured by a digital circuit or may be configured by an analogue circuit. Further, when a technology of making into an integrated circuit superseding integrated circuits at the present time appears due to advancement of a semiconductor technology, the integrated circuit by this technology is also able to be used.
(307) As used herein, the term “and/or” should be interpreted to mean one or more items. For example, the phrase “A, B and/or C” should be interpreted to mean any of: only A, only B, only C, A and B (but not C), B and C (but not A), A and C (but not B), or all of A, B, and C. As used herein, the phrase “at least one of” should be interpreted to mean one or more items. For example, the phrase “at least one of A, B and C” or the phrase “at least one of A, B or C” should be interpreted to mean any of: only A, only B, only C, A and B (but not C), B and C (but not A), A and C (but not B), or all of A, B, and C. As used herein, the phrase “one or more of” should be interpreted to mean one or more items. For example, the phrase “one or more of A, B and C” or the phrase “one or more of A, B or C” should be interpreted to mean any of: only A, only B, only C, A and B (but not C), B and C (but not A), A and C (but not B), or all of A, B, and C.
CROSS REFERENCE
(308) This Nonprovisional application claims priority under 35 U.S.C. § 119 on provisional Application No. 63/059,024 on Jul. 30, 2020, the entire contents of which are hereby incorporated by reference.

Claims

1. A user equipment (UE) that communicates with a base station apparatus, comprising: receiving circuitry configured to: receive a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; receive an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; receive an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; and receive an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and transmitting circuitry configured to transmit, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol Xbeing defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed, which is a time required for the UE to prepare PUSCH data after receiving an uplink (UL) grant, after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.
2. A base station apparatus that communicates with a user equipment (UE), comprising: transmitting circuitry configured to: transmit a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; transmit an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; transmit an RRC message comprising third information used for indicating a scaling factor

for reduced UE PUSCH preparation time; and transmit an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and receiving circuitry configured to receive, from the UE, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol Xbeing defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed, which is a time required for the UE to prepare PUSCH data after receiving an uplink (UL) grant, after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.

3. A communication method of a user equipment (UE) that communicates with a base station apparatus, comprising: receiving a radio resource control (RRC) message comprising first information used for indicating a reduced UE processing capability from a set of multiple reduced UE processing capabilities; receiving an RRC message comprising second information used for indicating a numerology for a Physical Uplink Shared Channel (PUSCH) transmission; receiving an RRC message comprising third information used for indicating a scaling factor for reduced UE PUSCH preparation time; receiving an RRC message comprising fourth information used for indicating an offset for reduced UE PUSCH preparation time; and transmitting, to the base station apparatus, a transport block if the first uplink symbol in the PUSCH allocation for a transport block including a Demodulation Reference Signal (DM-RS) is no earlier than at symbol X, symbol Xbeing defined as the next uplink symbol with its Cyclic Prefix (CP) starting T.sub.proc,2,relaxed, which is a time required for the UE to prepare PUSCH data after receiving an uplink (UL) grant, after the end of reception of the last symbol of the Physical Downlink Control Channel (PDCCH) carrying a downlink control information (DCI) scheduling the PUSCH, wherein T.sub.proc,2,relaxed is determined by the first information, the second information, the third information, the fourth information and a predefined table including a set of UE PUSCH preparation time.