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FILING RECEIPT



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24374
VOLPE AND KOENIG, P.C.
DEPT. ICC
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PHILADELPHIA, PA 19103

Date Mailed: 08/20/2019

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Inventor(s)

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Applicant(s)

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Power of Attorney: The patent practitioners associated with Customer Number 24374

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Permission to Access Search Results: Yes

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The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/886,173**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No
Title

METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Application Number	Not yet known
Filing Date	August 13, 2019
First Named Inventor	Mahmoud Taherzadeh Boroujeni et al.
Title	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR
Art Unit	N/A
Examiner Name	N/A
Attorney Docket Number	IDC-14850US01

SIGNATURE of Applicant or Patent Practitioner

Signature	/Todd A. Norton/	Date (Optional)	August 13, 2019
Name	Todd A. Norton	Registration Number	48636
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)	IDAC HOLDINGS, INC.		

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.



*Total of 1 forms are submitted.

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Application Number	Filing Date

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- OR
- ☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

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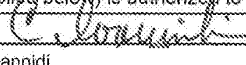
I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

IDAC Holdings, Inc.

- ☐ Inventor or Joint Inventor (title not required below)
- ☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)
- ☒ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)
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The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature		Date (Optional)	9 January 2012
Name	Christos A. Ioannidi		
Title	Senior Patent Executive		

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Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		
First Named Inventor/Applicant Name:		Mahmoud Taherzadeh Boroujeni		
Filer:		Todd A. Norton/Sheila De Padilla		
Attorney Docket Number:		IDC-14850US01		
Filed as Large Entity				
Filing Fees for Provisional				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
PROVISIONAL APPLICATION FILING	1005	1	280	280
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				280

Electronic Acknowledgement Receipt	
EFS ID:	36863918
Application Number:	62886173
International Application Number:	
Confirmation Number:	5679
Title of Invention:	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR
First Named Inventor/Applicant Name:	Mahmoud Taherzadeh Boroujeni
Customer Number:	24374
Filer:	Todd A. Norton/Sheila De Padilla
Filer Authorized By:	Todd A. Norton
Attorney Docket Number:	IDC-14850US01
Receipt Date:	13-AUG-2019
Filing Date:	
Time Stamp:	17:34:06
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$280
RAM confirmation Number	E20198CH34553491
Deposit Account	090435
Authorized User	Sheila De Padilla
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		14850US01_Application_EFS.PDF	250303	yes	52
			dd67787f6c5d259335f2eb8d011a9a96e320df12		
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Specification		1	49	
	Claims		50	51	
	Abstract		52	52	
Warnings:					
Information:					
2	Drawings-other than black and white line drawings	14850US01_Drawings_EFS.PDF	2835208	no	21
			86141ceb9e762f6f2d90d1e12e4572dae2c8a648		
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3	Application Data Sheet	14850US01_ADS_EFS.PDF	1256582	no	10
			1e36d249c1360e192666bdc35db7f2bd90a053b86		
Warnings:					
Information:					
4	Power of Attorney	14850US01_POA_EFS.PDF	377782	no	2
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Warnings:					
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5	Fee Worksheet (SB06)	fee-info.pdf	30023	no	2
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METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR

BACKGROUND

[0001] In New Radio (NR) for 5G wireless systems, a new structure and design is adopted for the physical uplink shared channel (PUCCH) for transmitting uplink data, as well as its scheduling via the physical downlink control channel (PDCCH).

SUMMARY

[0002] Methods and apparatus for uplink (UL) multiplexing and prioritization involving cancellation, interrupts, or preemption of PUCCH, eMBB UE, URLLC UE, PUSCH, and PRACH. Specifically methods are disclosed for performing PUCCH cancellation or modification. Methods are disclosed for eMBB UE cancellation and URLLC UE pre-emption with a cancellation/scheduling indication decoding failure. Methods are also disclosed for signaling of PUSCH cancellation. Methods are also disclosed for a selection procedure of power control and transmission parameters by the interrupting UE. Methods are also disclosed for performing PRACH cancellation or modification. Methods to determine whether the cancellation indication is applicable to a given UE are disclosed. Methods to reduce PDCCH monitoring/save power while monitoring the cancellation indication are disclosed. Methods to adapt retransmission of a dropped TB due to inter-UE cancellation, including interactions with MAC layer are disclosed. Methods for providing cross-carrier cancellation indication are disclosed. Methods to ensure DMRS orthogonality in Power-based inter-UE multiplexing and prioritization are disclosed. Methods for Confirmation/Continuation indication in inter-UE multiplexing and prioritization are disclosed. Cancellation/Confirmation using priority levels in inter-UE multiplexing and prioritization are disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0004] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0005] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0006] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0007] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0008] FIG. 2 is an example diagram of PUCCH resource identification based on UL cancellation indication;

[0009] FIG. 3 is a flowchart of an WTRU Procedure for adaptation of PUCCH format and resources based on UL cancellation indication;

[0010] FIG. 4 is a diagram showing both an eMBB and URLLC WTRU Frame structure;

[0011] FIG. 5 is a flowchart showing procedures for an eMBB WTRU and URLLC WTRU;

[0012] FIG. 6A is a flowchart showing an example of an eMBB WTRU procedure for adaptation of UL transmission with configured grant, in presence of an explicit indication of cancelled UL resources by GC-DCI;

[0013] FIG. 6B is a flowchart showing an example of an eMBB WTRU procedure for adaptation of UL transmissions with dynamic grant;

[0014] FIG. 7 is a flowchart showing an example of WTRU procedure to determine the set of cancelled resources, based on a combination of semi-static configuration and dynamic indication through GC-DCI;

[0015] FIG. 8 illustrates the URLLC WTRU Cancellation Monitoring;

[0016] FIG. 9 illustrates an example, where the WTRU, rather than having 10 monitoring occasions, only has 4 monitoring occasions based on a combination of the U cancellation monitoring configuration with the URLLC WTRU transmission configuration;

[0017] FIG. 10 illustrates eMBB CG WTRU and URLLC CG WTRU (Cancellation);

[0018] FIG. 11 illustrates an eMBB DG WTRU and URLLC CG WTRU (Cancellation);

[0019] FIG. 12 illustrates an eMBB CG WTRU- URLLC DG WTRU with WTRU specific configuration;

[0020] FIG. 13 illustrates an eMBB CG WTRU- URLLC DG WTRU with grouped WTRU configuration;

[0021] FIG. 14 is a flowchart showing an example of URLLC WTRU procedure for the selection “transmission mode” in grantless UL transmission;

[0022] FIG. 15 is a diagram illustrating an example of grantless UL transmission by URLLC WTRU in “congested” and “uncongested” transmission modes, based on the presence of UL cancellation indication;

[0023] FIG. 16 shows an example flow diagram of a WTRU procedure for adaptation of PRACH format and resources based on the dynamic UL cancellation indication;

[0024] FIG. 17 shows an example where there is no interruption and the eMBB WTRU transmits for an entire scheduled duration;

[0025] FIG. 18 shows an example where there is interruption and the eMBB WTRU skips transmitting in the resource occupied by a URLLC WTRU; and

[0026] FIG. 19 illustrates eMBB transmission with interruption where eMBB transmits preemptive DMRS that is orthogonal to the URLLC transmission.

DETAILED DESCRIPTION

[0027] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0028] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network (CN) 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c,

102d, any of which may be referred to as a station (STA), may be configured to transmit and/or receive wireless signals and may include a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0029] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (NR) NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0030] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, and the like. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0031] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0032] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed Uplink (UL) Packet Access (HSUPA).

[0033] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0034] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using NR.

[0035] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0036] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0037] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for

use by drones), a roadway, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106.

[0038] The RAN 104 may be in communication with the CN 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104 and/or the CN 106 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104 or a different RAT. For example, in addition to being connected to the RAN 104, which may be utilizing a NR radio technology, the CN 106 may also be in communication with another RAN (not shown) employing a GSM, UMTS, CDMA 2000, WIMAX, E-UTRA, or WiFi radio technology.

[0039] The CN 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0040] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c

shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0041] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0042] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0043] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0044] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0045] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element

122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0046] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0047] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0048] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0049] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio

unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors. The sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor, an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, a humidity sensor and the like.

[0050] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and DL (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the DL (e.g., for reception)).

[0051] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0052] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0053] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0054] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0055] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0056] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0057] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0058] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0059] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0060] In representative embodiments, the other network 112 may be a WLAN.

[0061] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have access or an interface to a Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example,

where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an “ad-hoc” mode of communication.

[0062] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0063] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0064] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0065] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and

802.11ac, 802.11af supports 5 MHz, 10 MHz, and 20 MHz bandwidths in the TV White Space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support Meter Type Control/Machine-Type Communications (MTC), such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0066] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode) transmitting to the AP, all available frequency bands may be considered busy even though a majority of the available frequency bands remains idle.

[0067] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0068] FIG. 1D is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0069] The RAN 104 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 104 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to,

and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0070] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0071] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0072] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, DC, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0073] The CN 106 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0074] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of non-access stratum (NAS) signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0075] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 106 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 106 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating WTRU IP address, managing PDU sessions, controlling policy enforcement and QoS, providing DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0076] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184a, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering DL packets, providing mobility anchoring, and the like.

[0077] The CN 106 may facilitate communications with other networks. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs

102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local DN 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0078] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0079] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or performing testing using over-the-air wireless communications.

[0080] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0081] In NR, for data transmission, Transport Block (TB) is a unit of data transmission consisting of one or multiple CBs. Code Block (CB) is a part of data that is associated with one block of error correction code and one CRC. Code Block group (CBG) is a group of CBs that are associated with a single bit for ACK-NACK. One transport block may consist of multiple CBGs. The maximum of number CBGs per TB is configured by higher layer signaling.

[0082] In NR and LTE, data transmission is generally scheduled dynamically by gNB using downlink control information (DCI) which is transmitted by PDCCH.

[0083] The time domain assignment for PUSCH is scheduled by DCI as the following (where SLIV stands for “start and length indicator value”).

[0084] The starting symbol S relative to the start of the slot, and the number of consecutive symbols L counting from the symbol S allocated for the PUSCH are determined from the start and length indicator SLIV of the indexed row:

if $(L-1) \leq 7$ then

$$SLIV = 14 \cdot (L-1) + S$$

else

$$SLIV = 14 \cdot (14-L+1) + (14-1-S)$$

where $0 < L \leq 14-S$

[0085] In 5G NR, downlink preemption procedure is specified as the following. A set of serving cells by higher layer parameter INT-ConfigurationPerServingCell that includes a set of serving cell indexes provided by corresponding higher layer parameters servingCellId and a corresponding set of locations for fields in DCI format 2_1 by higher layer parameter positionInDCI. An information payload size for DCI format 2_1 by higher layer parameter dci-PayloadSize. An indication granularity for time-frequency resources by higher layer parameter timeFrequencySet.

[0086] The content of the DCI carrying the “downlink preemption indication” indicates the frequency and the time of the preempted resources, including the corresponding symbols.

[0087] IN R15 power control, the PUSCH received power may be estimated as shown in Table 1.

$$PUSCH_Rx_power = \min(p_{max}, Po(j) + a(j)PL(q) + 10 \log_{10}(2^u M) + \delta_{TF} + \delta_f(l))$$

- $PL(q)$: path loss estimate from CSI-RS or SSBLOCK: q is per beam pair with a maximum of 4 beam pairs tracked
- $Po(j)$: target received power:
- $a(j)$: fractional path loss compensation factor $0 < a < 1$:

$$Prx = Po + a PL - PL$$

- $a = 1$, $Prx = Po$: pure power control e.g. CDMA, cell edge interference to OBSS high

- $a = 0$, $P_{rx} = P_o - PL$: no power control
- $0 < a < 1$: $P_{rx} = P_o + a PL - PL$: fractional path-loss compensation, balance TPC out-of-cell interference
- P_o and a are open loop parameters indexed by j .
 - J tracks the types of transmissions: message-3 RACH (0) $\{a = 1\}$, grant free PUSCH (1) and grant based PUSCH
 - Note that j is indexed on the SRI (q) i.e. beam based
- $2^u M$: multiplied by number of RBs and scaled by the numerology (15 kHz = 0)
- Δ_{TF} : Transport format factor that varies by number of information bits per resource element= $10 \log(2^{1.25 \gamma} - 1)$ β : 80% of Shannon capacity.
 - β : used if PUSCH carries L1 control
 - γ : number of information bits in PUSCH transmission/(Total_REs – DMRS_REs).
 - Used for single layer transmission and if there is no fractional power control.
- Δ_f : closed loop power control carried in TPC field in DCI 0-0 and 0-1 or 202.
 - 2 bits: -1 dB, 0 dB, +1 dB +3 dB
- Pucch: same as PUSCH but $a = 1$ and carried in DL control DCI 1-0 and 1-1

Table 1.

[0088] In 5G NR, new enhancements are needed to improve the reliability of URLLC UL transmission. One of these enhancements is the option of cancelling eMBB UL data transmission, when a URLLC WTRU needs the resources.

[0089] The new enhancements described herein, address seven problems.

[0090] Problem 1: In NR, PUCCH is used by the WTRU for transmission of critical feedback information (e.g., HARQ-Ack, SR, etc.) to gNB. In case the eMBB WTRU is configured with UL cancellation, the eMBB WTRU may need to cancel UL transmission including PUCCH on time-frequency resources which overlap with UL transmissions from URLLC UE. If the PUCCH is canceled the eMBB WTRU may not be able to transmit a SR to request an UL grant from gNB or the HARQ-Ack corresponding to a received PDSCH. In the latter case, the gNB cannot assume that the eMBB WTRU has correctly detected the DL packet transmitted in the corresponding PDSCH and therefore may need to retransmit the DL packet which results in system throughput loss. Accordingly, a mechanism is needed to make sure the eMBB WTRU which is configured with UL cancellation to be able to transmit essential feedbacks in UL.

[0091] Problem 2: In inter-UE eMBB and URLLC multiplexing, the gNB may send a cancellation indication, e.g. an indication sent in a GC-PDCCH, to the eMBB WTRU to cancel its transmission for a duration and send a scheduling indication, e.g. a DCI transmitted in a WTRU specific DCI, to the URLLC WTRU to use the cancelled resources. The success or failure of the WTRUs in decoding either the cancellation indication or the scheduling indication may impact the performance of the URLLC transmission. In the case that there is a failure to decode one or more of the indications (i.e., in either the decoding of the cancellation indication (by the eMBB WTRU) or the scheduling indication (by the URLLC WTRU)), methods are needed to enable recovery of the URLLC WTRU transmission especially in the case that the latency requirements are very stringent.

[0092] Problem 3: Another problem is how to design an efficient cancellation procedure and how to signal it to eMBB users without using excessive control resources and with a good trade-off between the signaling overhead and the scheduling flexibility. A related problem is how the WTRU could monitor the cancellation indication timely without consuming considerable power. Furthermore, given the cancellation indication can be indicated on a GC-PDCCH signal, how could the eMBB WTRU determine that the indication is applicable to it, and how could the URLLC WTRU determine that the cancellation indication is not applicable to it.

[0093] Problem 4: Another problem is how to support inter-WTRU uplink multiplexing/prioritization, when the URLLC WTRU is using grantless UL transmission (or UL with configured grant). In this case, UL cancellation indication may not be feasible at the beginning, because the gNB is not aware of the UL transmission from the URLLC WTRU until it detects it.

[0094] Problem 5: Another problem is how to generalize UL multiplexing/prioritization for UL transmission other than PUSCH, for example PRACH and SRS. To apply UL multiplexing/prioritization to other channels, the main question is how to design efficient procedures that provide the added scheduling flexibility without excessive changes in the 5G NR specifications.

[0095] Problem 6: when a carrier is configured in time-division duplex (TDD) mode, the UE is only capable of either transmitting (uplink) or receiving (downlink) on a given time slot. For an eMBB UE, receiving a cancellation indication while transmitting uplink data on the same carrier becomes not possible. A problem is how to indicate to the UE the uplink cancellation indication when the carrier is configured in TDD mode. How a cancellation indication can indicate a cancellation on a different carrier than the one used to receive the indication.

[0096] Problem 7: it has been shown that when using Enhanced UL power control for UL inter-UE Tx prioritization/multiplexing, enhanced dynamic power boosting for URLLC UE, including dynamic change of power control parameters (e.g. P0 and alpha without SRI configured) and enhanced TPC (e.g. increased TPC

range and finer granularity) may offer benefits. Note that the need of URLLC UE power change during one transmission instance has not been considered and it is assumed that there is no change of eMBB UE power control scheme. Further benefits (i.e. no losses) have been observed when the gNB uses an SIC receiver to separate the transmission. This may require that the channel estimate of both the eMBB UE and the URLLC UE be clean. In this case, methods are needed to ensure that the DMRS can be separated with little or no interference.

[0097] In the following, a reference symbol is used to denote a symbol such as a complex number that is fixed and known and used as a pilot. Reference signal is used to denote the time domain signal that is generated after processing the reference symbols. For example, in OFDM, reference symbols are the complex numbers that are fed into the IDFT block while reference signal is the output of the IDFT block. In NR, a slot is a unit in the time grid that includes 14 OFDM symbols. Downlink control information (DCI) is a set of bits that are transmitted over a PDCCH for a user or a group of users. Resource element (RE) is one OFDM symbol on one subcarrier, and resource element group (REG) refers to a group of REs used as building blocks of control channel element (CCE) which assign resource elements to a user. Adjacent REGs in time or frequency that are grouped together and their associated precoder is the same are called REG bundles.

[0098] NR-REG, NR-CCE, and NR-PDCCH refer to REG, CCE, and PDCCH for the new radio (NR) in 5G. WTRU and user are used interchangeably and refer to the same thing. Also, gNodeB and gNB refer to the same thing. A control resource set (CORESET) is a set of resource elements used for downlink control channel, configured by its frequency resources and its length in time (in terms of symbols) and the type of its REG bundles. A search space (or a set of search spaces) is a set of PDCCH candidates that are monitored by a WTRU or a group of WTRUs during blind detection of PDCCH. A Code Block (CB) is a part of data that is associated with one block of error correction code and one CRC. Code Block group (CBG) is a group of CBs that are associated with a single bit for ACK-NACK. Transport Block (TB) is a unit of data transmission consisting of one or multiple CBs. Start and length indicator value (SLIV) is a parameter that is used for time domain allocation of data transmission.

[0099] The following describes methods for PUCCH cancellation which may be a solution to the problems described above.

[0100] One approach to enhance the reliability of UL transmission for URLLC users is that the scheduler provides an UL grant or configures PUCCH resources for the URLLC UEs which overlap with the time-frequency resources that are assigned for UL transmission by the eMBB UEs.

[0101] In one embodiment, the eMBB UEs may receive an indication to cancel UCI transmission on the configured or dynamically indicated PUCCH resources which entirely or partially overlap with the time-frequency resources configured for UL transmission by the URLLC UEs.

[0102] In another embodiment, the eMBB WTRUs which are subject to UL cancellation may be configured with two (or more) PUCCH resource sets for each range of UCI information bits O_{UCI} payload (e.g., $O_{\text{UCI}} \leq 2$, $2 < O_{\text{UCI}} \leq N_2$, $N_2 < O_{\text{UCI}} \leq N_3$, $N_3 < O_{\text{UCI}} \leq 1706$ bits where N_2 & N_3 are provided by higher layer), wherein a *primary PUCCH resource set* which can be used by the WTRU for UCI transmission during normal operation with no UL cancellation, and a *secondary PUCCH resource set* which can be used by the WTRU for UCI.

[0103] In one method, if an eMBB WTRU detects an indication that the transmission from the WTRU should be cancelled on certain PRBs and in symbols, then the WTRU may determine whether the indicated UL resources subject to cancellation overlap with the primary PUCCH resource set.

[0104] If that is the case, the WTRU may refrain from UCI transmission on the PUCCH resource (i.e., PUCCH cancellation) which belongs to the primary PUCCH resource set, and then the WTRU may transmit UCI on the PUCCH resource which belongs to the secondary PUCCH resource set. Alternatively, the WTRU may multiplex UCI with data and transmit on a grant-based PUSCH resource. Or, in case the WTRU doesn't have an UL grant, the WTRU may use a configured PUSCH resource (i.e., grant-free UL resource) which doesn't overlap with the indicated UL resources subject to cancellation for transmission of both data and UCI. In another embodiment, an eMBB WTRU which is configured for UL cancellation may determine a PUCCH format based on the overlap pattern between the PUCCH resources and the indicated PRBs and symbols over which the UL transmission to be cancelled by the UE. According to this method, the WTRU may do any of the following three actions.

[0105] First, the WTRU may determine whether the indicated UL resources subject to cancellation overlap with the *primary PUCCH format* from a first set of PUCCH resources. Second, the WTRU may determine a *secondary PUCCH format* from a second set of PUCCH resources which doesn't overlap with the indicated UL resources subject to cancellation. Third, the WTRU may Transmit the UCI on the *secondary PUCCH format* from a secondary set of PUCCH resources. FIG. 2 is an example diagram of PUCCH resource identification based on UL cancellation indication with 14 symbols in the Slot domain and up to 4 subcarriers in the System BW domain. As shown in FIG. 2, the first symbol is allocated for a Long PUSCH format. The second and third symbols are allocated to a Short PUCCH format which may overlap with UL resources. The fourth and fifth symbols are also Short PUCCH formats where both the fourth and fifth symbols are allocated to the primary PUCCH format. The fifth symbol is also allocated to the secondary PUCCH format.

[0106] In one example shown in FIG. 2, the WTRU transmitting 1-2 UCI information bits may perform any of the following three actions. First, the WTRU may determine that *the primary PUCCH format* is PUCCH format 1 over 4 symbols (i.e., Long PUCCH format). Second, the WTRU may determine that one or more symbols of the determined PUCCH format 1 overlaps with the indicated UL resources subject to cancellation (e.g., 2 symbols shown in FIG. 2). Third, the WTRU may use PUCCH format 0 over 1 symbol (i.e., Short PUCCH format) as a *secondary PUCCH format* for 1-2 bits UCI transmission.

[0107] In another example, the WTRU transmitting 1-2 UCI information bits may perform any of the following four actions. First, the WTRU may determine that *the primary PUCCH format* is PUCCH format 1 and a first symbol for the PUCCH transmission provided by higher layer (e.g., parameter *startingSymbolIndex*). Second, the WTRU may determine that one or more symbols of the determined PUCCH format 1 overlaps with the indicated UL resources subject to cancellation. Third, the WTRU may use a shortened PUCCH format 1 as a *secondary PUCCH format* with a different first symbol for the PUCCH transmission. Fourth, the WTRU may determine that the first symbol of *the secondary PUCCH format* is greater than first symbol of *the primary PUCCH format*.

[0108] The WTRU which is configured with multiple sets of PUCCH resources may perform any of the following five actions. First, the WTRU may determine whether the indicated UL resources subject to cancellation overlap with *the primary PUCCH format* for a given PUCCH resource set. Second, the WTRU may sequentially examine each PUCCH resource set by incrementing the PUCCH resource set index (e.g., *pucch-ResourceSetId+1* where *pucch-ResourceSetId* is provided by higher layer). Also in the second action, alternatively, the WTRU may examine a pre-specified list of PUCCH resource sets. Third, the WTRU may determine a *secondary PUCCH format* in each PUCCH resource set which doesn't overlap with the indicated UL resources subject to cancellation. Fourth, the WTRU may transmit the UCI on the *secondary PUCCH format* from a secondary PUCCH resource set. Fifth, the WTRU may determine that the *pucch-ResourceSetId* of the *secondary PUCCH format* is greater than the *pucch-ResourceSetId* of the *primary PUCCH format*.

[0109] The WTRU which is configured with a single PUCCH resource set comprising a list of PUCCH resource indexes (i.e., *pucch-ResourceId*) may perform any of the five actions. First, the WTRU may determine whether the indicated UL resources subject to cancellation overlap with *the primary PUCCH format* of the configured PUCCH resource set. Second, the WTRU may sequentially examine each PUCCH resource within the configured PUCCH resource set by incrementing the PUCCH resource index (e.g., *pucch-ResourceId+1* where *pucch-ResourceId* is provided by higher layer). Also concerning the second action, alternatively, the WTRU may examine a pre-specified list of PUCCH resources. Third, the WTRU may determine a *secondary*

PUCCH format within the configured PUCCH resource set which doesn't overlap with the indicated UL resources subject to cancellation. Fourth, the WTRU may transmit the UCI on the *secondary PUCCH format* from the configured PUCCH resource set. Fifth, the WTRU may determine that the *pucch-ResourceId* of the *secondary PUCCH format* is greater than the *pucch-ResourceId* of the *primary PUCCH format*.

[0110] In one embodiment, if the WTRU configured with the dedicated PUCCH resource determines that the PUCCH resource overlap with the indicated UL resources subject to cancellation, the WTRU may use a PUCCH resource configured for transmission of HARQ-ACK information on PUCCH in an initial UL BWP.

[0111] In another embodiment, if the WTRU is configured with UL cancellation as well as a supplementary (SUL), may transmit the UCI on the PUCCH resources configured on the SUL even if the WTRU is configured by higher layer to transmit the UCI on PUCCH resources on the primary/paired UL cell/carrier.

[0112] In another embodiment, if the WTRU is configured with UL cancellation as well as multiple UL carriers/components, may transmit the UCI on the PUCCH resources of the secondary UL cell/carrier which may not be paired with the DL primary cell/carrier.

[0113] FIG. 3 is a flowchart of an WTRU Procedure for adaptation of PUCCH format and resources based on UL cancellation indication.

[0114] As shown in FIG. 3, an eMBB WTRU may receive a higher layer configuration including the set of PUCCH formats and the corresponding UL control resource sets.

[0115] Then, the eMBB WTRU may receive GC-DCI indicating cancelled time-frequency UL resources.

[0116] Following this, the eMBB WTRU may check if there is overlap with the resource set of the configured primary PUCCH format.

[0117] If there is no overlap, the eMBB WTRU may transmit UCI using the configured primary PUCCH format on the corresponding UL control resource set. The procedure would end here.

[0118] If there is overlap, the eMBB WTRU may determine the secondary PUCCH format and the corresponding UL control resource set. Then, the eMBB WTRU may transmit UCI using the determined PUCCH format on the corresponding UL control resource set.

[0119] As such, FIG. 3 shows an exemplary procedure for the eMBB WTRU that is configured with multiple PUCCH formats with different corresponding UL resource sets.

[0120] The following covers methods for eMBB WTRU cancellation and URLLC WTRU pre-emption with cancellation/scheduling indication decoding failure.

[0121] Four scenarios will be reviewed. The first scenario is for Cancellation Indication Decoding Failure and Scheduling Indication Decoding Success. The second scenario is for Cancellation Indication Decoding Success and Scheduling Indication Decoding Failure. The third scenario is for Cancellation Indication Decoding Failure and Scheduling Indication Decoding Failure. The fourth scenario is for Cancellation Indication Decoding Success and Scheduling Indication Decoding Success.

[0122] The following covers the first scenario of Cancellation Indication Decoding Failure and Scheduling Indication Decoding Success.

[0123] In this case, the eMBB WTRU continues to transmit while the URLLC WTRU also transmits in the resource assuming that the resource is clear. This may result in the failure of both the eMBB transmission and the URLLC transmission.

[0124] To ensure that the UL transmission from the URLLC WTRU is reliably received at the gNB, the URLLC WTRU and/or eMBB WTRU may assist the gNB in identifying that the cancellation indication decoding has failed and the eMBB WTRU still continues to transmit in the URLLC transmission resource (UL cancellation has not been successful). The gNB may then take steps to rectify the situation.

[0125] In one embodiment, for URLLC WTRU assisted cancellation success identification, the URLLC WTRU may be configured with Interference Measurement Resource(s) (IMR) or Zero Power Channel State Information Reference Symbol (ZP CSI-RS) resources where there is no transmission by the URLLC WTRU on these resources and data is rate matched around them. This allows the gNB to measure the energy/interference on these resources. The gNB may compare the power levels in the IMR resources with the power levels in the eMBB only resources and estimate if the eMBB WTRU successfully stopped transmitting, e.g. there is a drop in the power between the two resources, or if it failed to stop transmitting, e.g. there is no change in the power between the two resources.

[0126] In another embodiment, the eMBB WTRU and URLLC WTRU may jointly assist the gNB in cancellation success identification. The URLLC may be configured with IMR resources or ZP CSI-RS resources where there is no transmission by the URLLC WTRU on these resources and data is rate matched around them. The eMBB WTRU may be configured with a specific sequence, e.g. Demodulation Reference Symbol (DMRS) or CSI-RS. The eMBB WTRU transmits this sequence on the same IMR resources of the URLLC WTRU whenever it detects a cancellation indication from the gNB. This allows the gNB to detect the sequence and validate that the cancellation has been successful i.e. if the eMBB WTRU successfully stopped transmitting, e.g. the sequence is detected, or if it failed to stop transmitting, e.g. the sequence is not detected.

[0127] This transmission of the sequence by the eMBB WTRU in the IMR resources of the URLLC WTRU serves two functions.

[0128] The first function is to serve as an acknowledgement to the gNB on receipt of the cancellation indication. The gNB is able to identify the sequence and know that the eMBB WTRU has cancelled its transmission.

[0129] The second function allows for the eMBB WTRU to resume transmission after the cancellation with no phase discontinuity between the original transmission and the resumed transmission. The sequence transmitted by the eMBB WTRU may assist the gNB in interpolating the channel estimate before and after cancellation.

[0130] It should be noted that a dual solution would be the case where the eMBB WTRU is configured with IMR resources or a ZP CSI-RS while the URLLC WTRU transmits a sequence in this resource. As the eMBB WTRU is cancelled, and the URLLC WTRU RS is known at the gNB, successful reception/detection of the URLLC RS validates that the URLLC WTRU has successfully received its scheduling indication (the uplink grant).

[0131] A figure illustrating the frame structure with the IMR and sequences with preemption is shown in FIG. 4.

[0132] FIG. 4 shows a diagram of an eMBBB and URLLC WTRU Frame structure. As shown in FIG. 4, in the top part of the diagram labelled eMBBB UE. An eMBBB WTRU may utilize preemption indication (PI) to know whether such eMBBB WTRU should stop transmitting data shown by stop resource process. Resume resource process may then have eMBBB WTRU resume data transmission through any of the available resources (S1, S2, S3, or S4).

[0133] As shown in the lower part of FIG. 4, labelled URLLC UE. A URLLC WTRU may work with system indicator (SI) and URRLC RS to monitor and decide whether any of the IMR resources URRLC WTRU has available to it needs to be involved with termination of data transmission or boosting power on interrupted resources during URRLC WTRU's preemption transmission.

[0134] The eMBB WTRU may use the following procedure. This procedure may be split into six steps.

[0135] In the first step. The WTRU may receive higher layer configuration on the identification sequence to transmit during cancellation. This may be WTRU specific or a sequence common to all WTRUs.

[0136] In the second step. The WTRU may monitor for and receive a preemption indication (PI).

[0137] In the third step. The WTRU may receive information specific to the eMBB WTRU sequence/resource. This information may be separate from the PI (received on a dedicated DCI). The information may be transmitted with the PI (jointly encoded and received in the same DCI).

[0138] Additionally in the third step. The eMBB WTRU sequence configuration (e.g. resource) may be signaled explicitly in the PI. The signal may be a configuration for the sequence (e.g. CSI-RS, DMRS) that may match the time-frequency pattern of one or more URLLC IMR resources for one or more URLLC UEs. The signal may be an index to a predefined table or an index to an RRC configuration table.

[0139] Also in the third step. The eMBB WTRU sequence configuration may be signaled implicitly (e.g., by PI, DCI, RNTI). The signal may also include the URLLC IMR resource for the URLLC WTRU to the eMBB WTRU.

[0140] In the fourth step. The eMBB WTRU may stop data transmission during the cancellation resource.

[0141] In the fifth step. The eMBB WTRU may transmit the identification sequence in the resources corresponding to the IMR resource of the URLLC UE. In the case that the IMR resource length is shorter than the length of the identification sequence, the eMBB WTRU may transmit a subset of the identification sequence e.g. a truncated or sampled value of the sequence, to the gNB. Also, in the case that the IMR resource length is longer than the length of the identification sequence, the eMBB WTRU may transmit a sequence of appropriate length derived from the identification sequence e.g. a cyclic extension, to the gNB.

[0142] In the sixth step. The eMBB WTRU may stop transmission of its data or may resume transmission its data after the URLLC WTRU has stopped transmitting. It should be noted that if the eMBB WTRU resumes transmission. It may puncture the original transmission or it may shift the original transmission to avoid the outgoing resource.

[0143] Still focusing on the Cancellation Indication Decoding Failure and Scheduling Indication Decoding Success scenario. The URLLC WTRU may use the following procedure split into four steps.

[0144] In the first step. The WTRU may receive higher layer configuration on the IMR resources to use during preemption transmission.

[0145] In the second step. The WTRU may receive scheduling and transmission information (the uplink grant). This information may be separate from the PI (transmitted on a dedicated DCI). This information may be transmitted with the PI (jointly encoded and transmitted in the same DCI).

[0146] In the third step. The WTRU starts URLLC transmission in the assigned resource. The WTRU may rate match its data around the IMR resources during the cancellation period.

[0147] In the fourth step. The WTRU continues monitoring the PI and or the scheduling indicator. This is necessary in the case that the gNB identifies the failure of the PI and wants to terminate the transmission or e.g. boost the transmitted power on the interrupted resources.

[0148] Procedures for the eMBB WTRU and URLLC WTRU are shown in FIG. 5.

[0149] FIG. 5 is a flowchart showing procedures for the eMBB WTRU and URLLC WTRU described above. Starting with the left procedure labelled eMBB UE, the eMBB WTRU may receive higher layer configuration for identification sequences. Next, the eMBB WTRU may monitor and receive PI. Then, the eMBB WTRU may then receive information specific to the eMBB WTRU sequence or resource. Next, the eMBB WTRU may stop normal transmission. After that, the eMBB WTRU may transmit identification sequence in resources corresponding to URLLC IMR. Then, the eMBB WTRU may continue monitoring during transmission in case PI failed. What should be noted is that arrow indicates that the procedure may loop back depending on whether PI failed. Lastly, the eMBB WTRU may resume transmission.

[0150] Now, on FIG. 5, turning to the right procedure labelled URLLC UE. The URLLC WTRU may receive higher layer configuration for IMR resources. Next, the URLLC WTRU may receive scheduling and transmission information. Following that, the URLLC WTRU may start URLLC transmission. Next, the URLLC WTRU may continue monitoring during transmission in case PI failed. Lastly, the URLLC WTRU may end transmission.

[0151] In one embodiment, the URLLC WTRU may assume a higher probability of failure of the eMBB cancellation indication and modify its transmission to accommodate the possibility of interference e.g. by boosting its power or by transmitting with a lower MCS. The URLLC WTRU may be configured with multiple transmission parameter configurations (e.g. power levels, MCS etc.) and the scheduling DCI may indicate the appropriate configuration to use e.g. based on the capability of the interfering eMBB UE, or on the aggregation level or reliability with which the eMBB cancellation indication was sent. The solution combines the WTRU cancellation and Power methods in one scheme.

[0152] One embodiment involves transmitting the eMBB WTRU cancellation indication at the same high reliability levels as the URLLC scheduling indication. This ensures that the probability of either of the indications failing is approximately the same. This may not be possible if the two WTRUs have different capabilities.

[0153] The following addresses the Cancellation Indication Decoding Success and Scheduling Indication Decoding Failure scenario.

[0154] In the case of Cancellation Indication Decoding Success and Scheduling Indication Decoding Failure, the eMBB WTRU stops its transmission while the URLLC WTRU does not transmit in the cleared resource. This results in a wastage of the transmission resource.

[0155] In this embodiment, the gNB is able to identify this scenario by the silence in the channel. Alternatively, the gNB may be able to identify the scenario by identifying a sequence e.g. an RS, transmitted by the eMBB WTRU in configured resources that overlap with IMR resources of the URLLC WTRU.

[0156] In this embodiment, the gNB may (a) restart the entire procedure i.e. send new cancellation and scheduling indicators to the UEs or (b) send a new scheduling indicator the URLLC WTRU if there is still enough resource for it to receive the indicator, decode it and send its data to the gNB.

[0157] The following addresses the Cancellation Indication Decoding Failure and Scheduling Indication Decoding Failure scenario.

[0158] In this case of Cancellation Indication Decoding Failure and Scheduling Indication Decoding Failure, the eMBB WTRU continues its transmission while the URLLC WTRU does not transmit in the cleared resource. This results in failure of preemption.

[0159] Note that in the case the eMBB WTRU is configured to transmit an identifying sequence in configured resources that overlap with IMR resources of the URLLC WTRU, the gNB is able to identify this scenario by the fact that there is no identifiable sequence from either the eMBB WTRU or the URLLC WTRU.

[0160] The following addresses the Cancellation Indication Decoding Success and Scheduling Indication Decoding Success scenario.

[0161] In the case of Cancellation Indication Decoding Success and Scheduling Indication Decoding Success, the eMBB WTRU is able to successfully decode the cancellation indication and the URLLC WTRU is able to successfully decode the scheduling indication, the eMBB WTRU stops transmission and allows the URLLC WTRU to transmit in the resource. The eMBB WTRU may or may not resume transmission on completion of the URLLC WTRU transmission. Note that the two indications may be sent separately or as one signal.

[0162] The following addresses Behavior on Successful Reception of a PI.

[0163] In one embodiment concerning Behavior on Successful Reception of a PI, the eMBB WTRU may continue to monitor the scheduling indication resources even if it has been scheduled, to allow it to stop a cancellation period and restart another cancellation period in the case that the gNB assigns a new resource e.g. based on preemption failure. This to enable the gNB recover from a failure scenario identifies that there

has been a failure in the preemption procedure. Any information received by a successfully received PI may override the information received by a previously received PI even if the information from the previously received PI is still current. On identification of a failure the gNB may restart the preemption procedure immediately.

[0164] In another embodiment, the URLLC WTRU may continue to monitor the scheduling indication resources even if it has been scheduled, to allow it to terminate a transmission and possibly restart another transmission in the case that the gNB assigns a new resource e.g. based on preemption failure. This to enable the gNB recover from a failure scenario identifies that there has been a failure in the preemption procedure. Any information received by a successfully received SI may override the information received by a previously received SI even if the information from the previously received SI is still current. On identification of a failure the gNB may restart the preemption procedure immediately.

[0165] In another embodiment, the eMBB WTRU may monitor for multiple PIs from the gNB. The multiple PIs may all point to the same cancelled resource to reduce the probability of eMBB PI decoding failure.

[0166] In another embodiment, the eMBB WTRU may monitor for multiple PIs from the gNB. Each PI may point to a separate cancelled resource. The cancellation resources may be entirely orthogonal or may overlap to reduce the latency of the URLLC WTRU transmission on identification of a failed preemption procedure.

[0167] The following covers an embodiment of methods for PUSCH cancellation indication by GC-DCI and the corresponding PUSCH adaptation.

[0168] One embodiment for indication of PUSCH cancellation by group-common DCI is to explicitly indicate the cancelled/interrupted resources by the GC-DCI and have a procedure for the eMBB WTRU to determine the cancellation of its PUSCH or its adaptation based on the modified set of resources.

[0169] As an example, for the case of UL transmission with configured grant, the eMBB WTRU may determine the active set of UL resources for UL configured grant based on a combination of Pool of UL configured resources configured by higher layer signaling. The eMBB WTRU may also determine that a dynamically indicated set of cancelled resources may be indicated explicitly by GC-PDCCH carrying GC-DCI. For example, the cancellation indication may indicate a configured grant index, or a configured grant group index. Upon receiving a cancellation indication indicating a certain configured grant, the WTRU cancels the ongoing transmission (or the transmission that is about to start) on the indicated configured grant. Lastly, the eMBB WTRU may also determine that a timer indicating the validity/expiration of the UL cancellation period the timer can be triggered by MAC CE or DCI carrying cancellation indication. A component carrier applicable for cancellation may also be utilized.

[0170] An example of WTRU procedure for this method is shown in FIG. 6A.

[0171] FIG. 6A is a flowchart showing an of an eMBB WTRU procedure for adaptation of UL transmission with configured grant, in presence of explicit indication of cancelled UL resources by GC-DCI.

[0172] As shown in FIG. 6, an eMBB WTRU may receive higher layer configuration including the resource set for UL configured grant. Next, the eMBB WTRU may receive GC-DCI indicating cancelled UL resources. After that, through the decision diamond, the eMBB WTRU may check to see if there is overlap with the resource set for UL configured grant. If there is no overlap, the eMBB WTRU may transmit PUSCH with configured grant on the configured resource set, based on the procedure in NR. The procedure may end here. If there is overlap, the eMBB WTRU may determine the active resource set for PUSCH transmission with configured grant, based on the configured resource set and the cancelled UL resources indicated by GC-DCI. Lastly, if there is overlap, the eMBB WTRU may transmit PUSCH with configured grant by using the determined active resource set, instead of the configured resource set.

[0173] Figure 6B shows an example procedure for an eMBB WTRU for adaptation of UL transmission with dynamic grant, in presence of explicit indication of cancelled UL resources by GC-DCI. As an example, for the case of UL transmission with dynamic grant, the eMBB UE may determine the active set of UL resources based on a DCI that indicates the resources it should transmit in. A pool of UL dynamically indicated resources may be sent by the DCI. A set of cancelled resources may also be dynamically indicated. For example cancelled resources may be indicated explicitly by GC-PDCCH carrying GC-DCI. For example, the dynamic grant may be sent with an identifying index. The cancellation indication may indicate a specific dynamic grant based on the identifying index. Upon receiving a cancellation indication indicating a certain dynamic grant or set of dynamic grants, the WTRU cancels the ongoing transmission (or the transmission that is about to start) on the indicated dynamic grant.

[0174] A timer indicating the validity/expiration of the UL cancellation period may also be utilized. The timer can be triggered by MAC CE or DCI carrying cancellation indication. A component carrier applicable for cancellation may also be utilized. An example of UE procedure for this method is shown in FIG. 6B.

[0175] In the method of UL cancellation indication by GC-DCI, a WTRU may be provided by a higher layer parameter "*UplinkCancellation*" and is configured with an specific radio network temporary identifier (RNTI), which may be called "CAN-RNTI", for monitoring GC-PDCCH conveying a GC-DCI indicating the UL cancellation. This GC-DCI may have its specific format dedicated to UL cancellation indication (e.g. DCI format 2_4). This DCI format 2_4 is used for notifying the PRB(s) and OFDM symbol(s) where WTRU may assume no transmission is expected from the WTRU.

[0176] Alternatively the WTRU may use INT-RNTI (which is used for monitoring downlink preemption) for also monitoring UL cancellation. In this case, the DCI format 2_1 defined in NR may be used to convey both downlink preemption and uplink cancellation indication. Besides, the WTRU may determine which part of the DCI format 2_1 is indicating downlink preemption indication or UL cancellation indication, explicitly based on some higher layer configuration (e.g., when the WTRU is simultaneously configured with both UL cancellation and DL preemption) and/or implicitly based on other parameters (e.g., the DCI payload size or based on an additional field in the DCI itself). In the above scenario, the following information is transmitted by the DCI format 2_1 with CRC scrambled by INT-RNTI: [*Pre-emption indication 1, ..., Pre-emption indication N, UL Cancellation indication*].

[0177] In the case of being configured for monitoring UL cancellation, the WTRU may be also configured with a set of serving cells by higher layer parameter *CAN-ConfigurationPerServingCell* that includes a set of serving cell indexes provided by corresponding higher layer parameters *servingCellId* and a corresponding set of locations for fields in DCI format 2_3 by higher layer parameter *positionInDCI*. Also, the payload size of the GC-DCI conveying the UL cancellation indication may be semi-statically configured for the UE.

[0178] The GC-DCI for UL cancellation indication may carry a bitfield which can be mapped to the UL cancelled resources explicitly indicating the frequency and time of the cancelled resources in RBs and OFDM symbols. The granularity for time-frequency resources may be semi-statically configured by higher layer. This configuration may be the same or different from configuration of parameter granularity for time-frequency resources for downlink preemption indication. In one example, the granularity for time-frequency resources may be configured by higher layer parameter *timeFrequencySet*, which is also used downlink preemption indication. In one example, the bits of the UL cancellation indication may be grouped to several groups of the same size, and each group of bits corresponds to a subset of frequency bandwidth (i.e. a subset of PRBs of the bandwidth part) or a symbol or a subset of symbols in the monitoring period or a combination of the frequency and time subsets. In this case, the bits of each group may indicate cancellation in that time-frequency subset of resources.

[0179] Another method for indicating the cancelled resources through GC-DCI is to convey information about the cancelled resources in GC-DCI, such that together with the configuration, it can determine the set of cancelled UL resources (as shown in FIG. 7). As an example, a bit field in GC-DCI may indicate a subset of frequency resources (among the configured resources) that is corresponding to the cancellation. In this method, the frequency resources of the cancelled UL transmission are indicated relative to the configured

set/pool of resources for the configured UL grant, instead of being explicitly indicated (or being indicated relative to the corresponding bandwidth part).

[0180] Another issue in PUSCH cancellation indication is how to support resumption of PUSCH transmission after cancellation. One solution to support PUSCH cancellation with the possibility of automatic resumption by the WTRU is to indicate the resources for the resumed UL transmission by signaling the time shift (e.g., in terms of slots/mini-slots/symbols/monitoring periods) to be applied to the original grant. This time shift may be included in the cancellation indication as part of the DCI or may be implicitly obtained from other parts of the cancellation indication (e.g. time resources corresponding to the cancellation).

[0181] FIG. 7 is a flowchart showing an example of WTRU procedure to determine the set of cancelled resources, based on combination of semi-static configuration and dynamic indication through GC-DCI.

[0182] As shown in FIG. 7, a WTRU may receive higher layer configuration including resource set for UL configured grant. After that, the WTRU may receive GC-DCI indicating additional information about the cancelled UL resources. Next, the WTRU may determine the cancelled UL resources, based on the configured resource set and that the additional information about the cancelled UL resources. Following this, the WTRU may determine the active resource set for PUSCH transmission with configured grant, by removing the cancelled UL resources. Lastly, the WTRU may transmit PUSCH with configured grant by using the determined active resource set, instead of the configured resource set.

[0183] In some solutions, a WTRU may be configured to monitor a continuation indication or confirmation indication (Col) on at least one search space for PDCCH. The WTRU may initiate or continue a transmission that overlaps with a certain time-frequency resource only under a condition that it receives a continuation indication for such resource. Otherwise, the WTRU does not initiate or interrupts the transmission at least for the portion overlapping over the resource, and possibly for any portion occurring during or after the resource. A time-frequency resource may be signaled using, for example, same solutions described in this document for the cancellation or pre-emption indication. This approach has the benefit of enhancing the protection of high-priority transmissions since failure of decoding the indication by other WTRUs would not cause them to continue transmitting and interfering.

[0184] A confirmation indication may also be used to indicate that the WTRU performs a transmission using a non-reduced transmission power, or more generally according to a first set of transmission power parameters. Otherwise, the WTRU performs a transmission using a reduced transmission or according to a second set of transmission power parameters at least for the portion overlapping over the resource, or possibly for the whole duration of the transmission.

[0185] For example, a WTRU may be scheduled to perform a PUSCH, PRACH, PUCCH or SRS transmission and determine that the transmission overlaps with at least one resource concerned by a confirmation indication. Such determination may be based on a higher layer configuration indicating a set of resources in time and frequency and possibly recurring in the time domain, along with a search space configuration for the corresponding confirmation indication. For example, the higher layer configuration may indicate a subset of time symbols and resource blocks within a slot, the identity of a search space including periodicity and offset, and possibly a parameter indicating a time offset between a decoded Col and a set of corresponding resources. The confirmation indication may further indicate a subset of resources for which transmission can proceed among a set of corresponding resources (e.g. resources within a slot and bandwidth part), for instance using a bitmap. The WTRU may proceed with the transmission overlapping with a resource subject to a confirmation indication only if it received such confirmation indication for the resource.

[0186] Such determination may be based on Layer 1 signaling (e.g., a corresponding PDCCH or DCI for example a WTRU-specific PDCCH or a GC-PDCCH), from RRC configuration, from MAC-CE signaling or from a combination of all three signaling types. The signaling may indicate a set of resources in time and frequency and possibly recurring in the time domain. The signaling may also contain search space configuration for the corresponding confirmation indication or may point to information that is higher layer configured (e.g., a search space table) to signal this. For example, the signaling may indicate one or more of a subset of time symbols and resource blocks within a slot, the identity of a search space including periodicity and offset, and a parameter indicating a time offset between a decoded Col and a set of corresponding resources. The confirmation indication may further indicate a subset of resources for which transmission can proceed among a set of corresponding resources (e.g., resources within a slot and bandwidth part), for instance using a bitmap. The WTRU may proceed with the transmission overlapping with a resource subject to a confirmation indication only if it received such confirmation indication for the resource.

[0187] For any solution described in this document, such solution is also applicable where instead of receiving a cancellation indication for a given resource or transmission, the WTRU fails to receive a confirmation indication for such resource or transmission when subject to confirmation.

[0188] Prioritization aspects are described herein. For example, cancellation/confirmation using priority levels in inter-UE multiplexing is described below.

[0189] A transmission may be assigned a priority level or transmission profile, e.g. corresponding to eMBB or URLLC. Such priority level may be obtained from corresponding PDCCH or DCI (e.g. in case of HARQ-ACK, dynamic grant or configured grant type 2 for PUSCH, aperiodic SRS), from RRC configuration (e.g. in case of

configured grant type 1 for PUSCH, scheduling request) and/or from MAC (e.g. in case of scheduling request or PUSCH).

[0190] A cancellation indication (CI) or confirmation indication (Col) may be assigned a set of priority levels indicating applicability to a transmission of a given priority level. For example, a cancellation indication may only be applicable to priority levels below a certain level, such as a level corresponding to eMBB only. The set of applicable priority levels may be configured by RRC along with a set of resources subject to cancellation or confirmation indication. Alternatively, the applicable priority levels may be included as part of the cancellation or confirmation indication itself. For example, such indication may be in a field of the DCI or by the C-RNTI used to decode the PDCCH. In case only two priority levels are defined, a cancellation or confirmation indication may implicitly only be applicable to transmission of the lowest priority level. In such case, the WTRU may only monitor the indication for a transmission of the lowest priority.

[0191] In another method, the WTRU may monitor the cancellation indication in a multi-step process to determine the resource allocation of the cancelled resource and/or whether it is applicable to the WTRU. For example, the WTRU may first monitor a GC-DCI in a first step, possible on a preconfigured subset of coresets or search spaces. After receiving a first indication in the first step, the WTRU would then monitor the PDCCH on second set of PDCCH resources, coreset(s), search space(s), and/or DCI or RNTI formats to determine the resources applicable for cancellation, possibly at a better granularity. In one example, the cancellation indication in the first step may further indicate applicability to a subset of WTRUs, where applicability is indicated per a specific priority level, transmission profile, a WTRU capability, and/or an RNTI value.

[0192] In one example, a WTRU may be configured with a number of transmission profiles (or priority levels) by higher layers (e.g. RRC). The WTRU may determine the transmission profile (or priority level) for a given transmission based on a priority level signaling that is indicated to the WTRU part of a DCI and is applicable for the transmission (e.g. PUSCH or PUCCH transmission). The WTRU may alternatively determine the transmission profile (or the priority level) based on the highest priority LCH mapped to the transmission (or the LCH that is related to or triggered the transmission). The WTRU may alternatively determine the transmission profile (or the priority level) based on a semi-statically configured mapping between LCHs and transmission profiles, whereby the WTRU associates the transmission profile for the transmission according to the highest priority LCH mapped to, related to, or has triggered the transmission. The WTRU may further receive a cancellation indication with an associated priority level or a transmission profile, which may be used by the WTRU to determine whether it is applicable to it or not.

[0193] In one solution, the WTRU may be configured to monitor for the cancellation indication prior to the start of the transmission, and/or between the instance of resource allocation DCI reception and the PUSCH start. The WTRU may also determine that the resource applicable for cancellation has passed or started already. The WTRU may monitor the cancellation indication as a function of its capability and/or the priority level (or transmission profile) of its scheduled transmission. For example, the WTRU may monitor for the cancellation indication only if the priority level (or transmission profile) associated with the transmission is below a certain threshold and/or the WTRU is of a certain capability.

[0194] After receiving a cancellation indication, the WTRU may cancel the transmission if at least one of the following is satisfied. For example, the WTRU may cancel the transmission if the WTRU determines that the cancellation indication is applicable to it.

[0195] For example, the WTRU may cancel the transmission if the WTRU determines that the transmission to be potentially cancelled overlaps with the resource indicated part of the cancellation indication.

[0196] For example, the WTRU may cancel the transmission if the transmission profile of the transmission to be potentially cancelled is lower -or higher- than the transmission profile indicated by the cancellation indication.

[0197] For example, the WTRU may cancel the transmission if the priority level of the transmission to be potentially cancelled is lower than the priority level indicated by the cancellation indication.

[0198] For example, the WTRU may cancel the transmission if the WTRU determines that the overlapping part in both frequency and time domains is larger than a certain threshold, where by the threshold is either configured by higher layers and/or is dependent on the size of the resource of the ongoing transmission.

[0199] For example, the WTRU may cancel the transmission if the WTRU received the cancellation indication at least a minimum processing time before the applicable cancellation start time. The WTRU may be specified or configured with multiple cancellation points, whereby the WTRU may apply the next cancellation point that is at least a minimum processing time away from the instance in time it received the cancellation indication. For example, the WTRU may be specified to cancel a PUSCH transmission within a number of symbols (ie. 3 symbols) from the instance at which the WTRU receives the cancellation indication.

[0200] If the WTRU receives the cancellation indication prior to the start of a PUSCH or PUCCH to be cancelled -or before a certain minimum processing time from the start of the transmission, the WTRU may perform at least one of the following processes.

[0201] The WTRU may generate a CBG-based PUSCH transmission for the CBGs that do not overlap the resource indicated by the cancellation indication.

[0202] The WTRU may not generate a MAC PDU for the PUSCH grant if the PUSCH cannot be partially transmitted.

[0203] The WTRU may determine an alternative or an overflow resource to transmit the PDU -or UCI- on, if the transmission has not already started. For example, after determining that the cancellation indication refers to a certain configured grant index, the WTRU may select another configured grant with the same TBS if it also meets the configured LCP restrictions for the LCHs included in the PDU.

[0204] After receiving a cancellation indication with a priority level (or a transmission profile) lower than the that of the transmission to be potentially cancelled, the WTRU may adjust its transmission power or apply a different set of power control parameters to the transmission. Such may be further conditioned on receiving the cancellation indication prior to the start of a PUSCH or PUCCH to be cancelled -or before a certain minimum processing time from the start of the transmission-.

[0205] In certain scenarios, the network may not be aware that a WTRU has cancelled a PUSCH transmission, e.g. when the transmission has not yet started for a configured grant for an eMBB WTRU. After receiving a cancellation indication for an initial transmission intended for a configured grant, if the WTRU determines that it cannot use such configured grant resource, the WTRU may perform at least one of the following processes.

[0206] A WTRU may trigger a new BSR or a new SR, e.g. for the highest priority LCH that mapped to the cancelled PDU. Such may further depend on whether the a pending BSR or SR was cancelled due to inclusion of a BSR MAC CE in the cancelled PDU; for the UE may trigger a new BSR instead of a BSR that was cancelled due inclusion of a BSR MAC on a PDU dropped because of inter-UE cancellation.

[0207] A WTRU may generate an autonomous retransmission for the cancelled PDU on the next CG occasion for a CG with the same TBS. If the WTRU has stored the PDU in a certain HARQ PID buffer, the WTRU may generate the autonomous retransmission on the next CG occasion applicable to that HARQ PID. Else, the WTRU may select an applicable upcoming CG occasion with the same or a different HARQ process.

[0208] A WTRU may start a certain timer. After stopping the timer or timer expiry the WTRU may perform any of the above actions. The WTRU may stop such timer upon receiving a dynamic grant applicable for the cancelled PDU (e.g. indicating the same HARQ process ID).

[0209] A WTRU may start the configured grant timer applicable to the configured grant initially selected for the cancelled transmission and the corresponding HARQ process ID.

[0210] Finally, the WTRU may keep the RV number used for the cancelled PDU.

[0211] In certain scenarios, the WTRU may miss-decode the resource allocation indicated by the cancellation indication. The WTRU may erroneously cancel the transmission, though the network is not aware of the cancellation. After receiving a cancellation indication and/or cancelling a certain transmission, the WTRU may perform at least one of the following procedures.

[0212] A WTRU may trigger a new BSR or a new SR, e.g. for the highest priority LCH that mapped to the cancelled PDU. Such may further depend on whether the a pending BSR or SR was cancelled due to inclusion of a BSR MAC CE in the cancelled PDU.

[0213] A WTRU may generate an autonomous retransmission for the cancelled PDU on the next CG occasion for a CG with the same TBS. If the WTRU has stored the PDU in a certain HARQ PID buffer, the WTRU generates the autonomous retransmission on the next CG occasion applicable to that HARQ PID. Else, the WTRU may select an applicable upcoming CG occasion with a different HARQ process.

[0214] A WTRU may start a certain timer. After stopping the timer or timer expiry, the WTRU may perform any of the above actions. The WTRU may stop such timer upon receiving a dynamic grant applicable for the cancelled PDU (e.g. indicating the same HARQ process ID).

[0215] Efficient monitoring details may be configured. To reduce the monitoring overhead on the eMBB WTRU for the GC-PDCCH signaling in UL cancellation, the gNB may signal information on the possibility of a URLLC transmission occurring. This may be combined with the cancellation indication search space configuration to limit the overall monitoring of the cancellation indication to resources in which there may be a URLLC WTRU transmission. FIG. 8 illustrates the URLLC WTRU Cancellation Monitoring.

[0216] FIG. 9 illustrates a simple example, where the WTRU, rather than having 10 monitoring occasions, only has 4 monitoring occasions based on a combination of the U cancellation monitoring configuration with the URLLC WTRU transmission configuration. The URLLC WTRU transmission configuration may be sent dynamically to the eMBB WTRU using a WTRU specific signal e.g. a WTRU-specific PDCCH for example as part of the DCI scheduling the WTRU. The URLLC WTRU transmission configuration may be sent dynamically to the eMBB WTRU using a group signal, e.g., a GC-PDCCH. The URLLC WTRU transmission configuration may be sent semi-statically or statically to the eMBB WTRU using an RRC configuration or a MAC-CE transmission. This signal may indicate parameters such as the start, stop, periodicity and frequency resources of a CG or DG URLLC transmission that may possibly interrupt the transmission of a CG or DG eMBB WTRU.

[0217] The following scenarios may be utilized.

eMBB WTRU	URLLC WTRU
Configured Grant (CG)	Configured grant (CG)
Configured Grant (CG)	Dynamic Grant (DG)
Dynamic Grant (DG)	Configured Grant (CG)
Dynamic Grant (DG)	Dynamic Grant (DG)

[0218] For eMBB CG WTRU and URLLC CG WTRU (Cancellation), an eMBB CG WTRU scheduled in resources that have been configured for a URLLC CG WTRU may monitor for the cancellation indication only within the resources where there is overlap. The eMBB CG WTRU may need signaling to identify the resources in which the URLLC CG WTRU may transmit. This may enable it to monitor for the cancellation signal when there is overlap and reduce the monitoring overhead. The signaling to the eMBB WTRU may include parameters such as the frequency resources, the time resources or duration of transmission and the periodicity of the URLLC WTRU CG resources.

[0219] For both Type 1 and Type 2 configured grant scheduling for the eMBB CG WTRU, the information may be signaled as part of the RRC configuration signaling (Type 1) or activation signaling (Type2). This may be especially applicable in the case that the eMBB CG WTRU is configured or activated after the URLLC WTRU is configured or activated. For both Type 1 and Type 2 configured grant scheduling for the eMBB WTRU, the information may be explicitly signaled to the eMBB CG WTRU as an additional monitoring configuration. This may be especially applicable in the case that the eMBB CG WTRU is configured or activated before the URLLC WTRU is configured or activated. It may also be applicable in the case that the design wishes to keep the cancellation monitoring configuration/activation separate from the transmission configuration/activation.

[0220] In one example, the eMBB DG WTRU (or set of eMBB DG WTRUs) may receive a monitoring activation / deactivation signal at configured or pre-defined times indicating the resources in which cancellation monitoring should be activated or deactivated. The eMBB CG WTRU (or set of eMBB CG WTRUs) may monitor for cancellation when the URLLC resources are active. This is illustrated in FIG. 8.

[0221] FIG. 10 illustrates eMBB CG WTRU and URLLC CG WTRU (Cancellation). For eMBB DG WTRU and URLLC CG WTRU (Cancellation), an eMBB DG WTRU scheduled in resources that have been configured for URLLC CG WTRU may monitor for the cancellation indication only within the resources where they overlap. The eMBB DG WTRU may need signaling to identify the resources in which the URLLC CG WTRU may transmit. This enables the monitoring for the cancellation signal when there is overlap and reduce the monitoring overhead. The signaling to the eMBB WTRU may include parameters such as the frequency resources, the time resources or duration of transmission and the periodicity of the URLLC WTRU CG resources. Note that the periodicity may be needed in the case that the eMBB resources may span over multiple URLLC CG WTRU transmissions.

[0222] The information may be explicitly signaled to the eMBB DG WTRU as an additional monitoring configuration or as part of the DCI scheduling the DG transmission (WTRU-specific signaling). The information may explicitly be sent to all eMBB WTRUs (both CG and DG WTRUs) simultaneously and the eMBB WTRUs may combine this information with their scheduling information to decide if cancellation monitoring may be activated in certain resources (e.g., group signaling such as GC-PDCCH signaling or a group based sequence). In this case, the gNB may send signaling at appropriate intervals to inform all the WTRUs about the cancellation monitoring resources for the subsequent duration. In one example, the eMBB DG WTRU (or set of eMBB DG WTRUs) may receive a monitoring activation / deactivation signal at configured or pre-defined times indicated the resources in which cancellation monitoring should be activated or deactivated.

[0223] In FIG. 11 there is illustrated an eMBB DG WTRU and URLLC CG WTRU (Cancellation). An eMBB CG WTRU that may have a URLLC DC WTRU scheduled in the resources that it transmits in may need to monitor for a cancellation indication within the resources in which there may be overlap. The eMBB DG WTRU may need signaling to identify the resources in which the URLLC CG WTRU may transmit. The scheduling may enable it to monitor for the cancellation signal when there is overlap and reduce the monitoring overhead. The signaling to the eMBB WTRU may include parameters such as the frequency resources and the time resources within which the URLLC DC WTRU may be scheduled.

[0224] The resources dedicated to the eMBB CG WTRU may be set as off-limits to the URLLC DG WTRU to prevent the need for the eMBB CG WTRU to have to monitor for a cancellation indication.

[0225] The resources dedicated to the eMBB CG WTRU may be set as allowable to the URLLC DG WTRU to ensure that the eMBB CG WTRU may always monitor for a cancellation indication.

[0226] The resources dedicated to the eMBB CG WTRU may be partitioned to have resources both off-limits and allowable to the URLLC DG WTRU to ensure that the eMBB CG WTRU may always monitor for a cancellation indication within the allowable resource.

[0227] The signaling to enable the identification of the allowable and off-limits resources may be WTRU specific. The allowable/off-limits resources may be configured as part of the CG configuration (and WTRU specific) as shown in FIG. 12. The signaling to enable this may be common to multiple WTRUs (e.g., a GC-PDCCH) and may be signaled by a separate mechanism such as a GC-PDCCH as shown in FIG. 13.

[0228] FIG. 12 illustrates an eMBB CG WTRU- URLLC DG WTRU with WTRU specific configuration.

[0229] FIG. 13 illustrates eMBB CG WTRU- URLLC DG WTRU with grouped WTRU configuration. This may also be applicable to the eMBB DC WTRU-URLLC DG WTRU scenario.

[0230] For the eMBB DG WTRU-URLLC DG WTRU (Cancellation), an eMBB DG WTRU that has a URLLC DG WTRU scheduled in its resources may need to monitor for a cancellation indication within the resources in which they may overlap. The eMBB DG WTRU may need signaling to identify the resources in which the URLLC CG WTRU may transmit. The signaling may enable it to monitor for the cancellation signal when there is overlap and reduce the monitoring overhead. The signaling to the eMBB WTRU may include parameters such as the frequency resources and the time resources within which the URLLC DC WTRU may be scheduled.

[0231] The resources in which the eMBB DG WTRU may transmit may be set as off-limits to the URLLC DG WTRU to prevent the need for the eMBB DG WTRU to have to monitor for a cancellation indication.

[0232] The resources in which the eMBB DG WTRU may transmit may be set as allowable to the URLLC DG WTRU to ensure that the eMBB CG WTRU may always monitor for a cancellation indication.

[0233] The resources in which the eMBB CG WTRU may be transmit may be partitioned to have resources both off-limits and allowable to the URLLC DG WTRU to ensure that the eMBB CG WTRU may monitor for a cancellation indication within the allowable resource only. The signaling to enable this may be WTRU specific. The allowable/off-limits resources may be sent as part of the DCI scheduling the transmission. The signaling to enable this may be common to multiple WTRUs (e.g., a GC-PDCCH) and may be signaled by a separate mechanism as shown in FIG. 11.

[0234] Methods for autonomous hybrid power control and UL cancellation by WTRU are disclosed herein.

[0235] For the case of grantless uplink transmission by a URLLC WTRU (i.e., Configured Grant), sending a cancellation indication from the gNB at the beginning of the transmission is not practical as the gNB has to

know whether a URLLC WTRU is about to use the resource. One solution to support inter-WTRU UL multiplexing between URLLC and eMBB UEs in this case is to use power control and/or different MCS and/or transmission modes for the UL periods and/or slots where UL cancellation indication is not feasible (e.g., initial transmission). The gNB may send an UL cancellation signal at a later time during the transmission.

[0236] In one embodiment of this method, the URLLC WTRU may be configured with two or multiple UL transmission modes for the grantless UL transmission of PUSCH, e.g., “congested mode” or “uncongested mode.” With each mode corresponding to a set of power control parameters and/or modulation and coding scheme (MCS) and/or other transmission-related parameters. The selection of “congested mode” and “uncongested mode” transmission by the URLLC WTRU may be done based on the absence or presence of the UL cancellation indication, respectively. As an example, in absence of UL cancellation, the URLLC WTRU starts transmission with the transmission parameters corresponding to the “congested mode” (which may include transmitting with higher power level and/or lower rate). In the consecutive slots/mini-slots and/or UL periods, if the URLLC WTRU receives UL scheduling from the gNB, it switches to grant-based UL transmission with parameters based on the scheduling information. Otherwise, if the URLLC WTRU does not receive its UE-specific DCI for UL transmission but it detects an UL cancellation indication in GC-DCI, it continues grantless UL transmission, but using the parameters corresponding to the “uncongested transmission” mode (see FIG. 8).

[0237] FIG. 14 is a flowchart showing an example of URLLC WTRU procedure for the selection “transmission mode” in grantless UL transmission. As shown in FIG. 14, the URLLC WTRU may receive higher layer configuration including the resource set for UL configured grant and parameters of the two transmission modes (“congested” and “uncongested”). Next, the URLLC WTRU may monitor GC-DCI indicating cancelled UL resources. After that, the URLLC WTRU may determine whether UL cancellation for the next slot or min-slot or UL period. If there was no cancellation, the URLLC WTRU may transmit PUSCH on the configured resources with transmit parameters (e.g., power control parameters and MCS) corresponding to the “congested transmission mode.” If there was a cancellation, the URLLC WTRU may transmit PUSCH on the configured resources with transmit parameters (e.g., power control parameters and MCS) corresponding to the “uncongested transmission mode.”

[0238] In this method, the URLLC WTRU may start a new UL grantless transmission with “uncongested mode” transmission, as long as the previously monitored UL cancellation is still valid. For example, the URLLC WTRU may start grantless uplink transmission in slot 0 and receive the UL cancellation indication in slot 1 (indicating UL cancellation for 4 slots) and finishes the transmission of that UL data in slot 1. In this case, the

URLLC WTRU may begin another grantless UL transmission with “uncongested transmission mode” parameters in slot 2 or slot 3 or slot 4 (see FIG. 15).

[0239] FIG. 15 is a diagram of an example of a grantless UL transmission by URLLC WTRU in “congested” and “uncongested” transmission modes, based on the presence of UL cancellation indication. As shown in FIG. 15, this transmission example is made up of four colored blocks. The first colored block represents slot 0 which is where a URLLC WTRU may start grantless uplink transmission. The second colored block represents slot 1 which is a UL cancellation request. The next three colored blocks represent slots 2-4, respectively. Slots 2-4 represent grantless transmissions by URLLC WTRU in “uncongested transition mode.”

[0240] In one method, the URLLC WTRU may switch between “congested mode” and “uncongested mode” based on the possible presence of an eMBB WTRU e.g. a pre-defined time-frequency region sending a configured grant to the gNB or a possible time-frequency “shared” region where both eMBB and URLLC traffic may be transmitting simultaneously.

[0241] Methods for PRACH cancellation or modification are described herein.

[0242] One approach to enhance reliability of UL transmission for URLLC users is to allow those users to transmit on the resources that are assigned for eMBB UEs to transmit PRACH. In this case, there should be some procedure to avoid PRACH transmission by eMBB UEs on the occupied resources.

[0243] One embodiment involves informing the eMBB UEs to modify or adapt their PRACH transmission to avoid collision with the interrupting URLLC transmission. In this method, the eMBB WTRU may be configured with multiple PRACH formats with different corresponding resource sets. As an example, an eMBB WTRU may be configured with two PRACH formats of F1 and F2 (where F2 may have a shorter length), and in the case of resource collision for the PRACH resources corresponding to format F1 (based on the received UL cancellation indication), the WTRU may determine that it should use F2 (as shown in FIG. 16) This configuration may be done using SIB2 or another higher layer signaling. In another example, instead of being configured with PRACH format of F2, the eMBB WTRU may switch to the default PRACH format of Format 0, if the resources corresponding to the configured format F1 overlap with the cancelled UL resources.

[0244] FIG. 16 is a flowchart showing a WTRU procedure for adaptation of PRACH format and resources based on the dynamic UL cancellation indication. As shown in FIG. 16, the WTRU may receive configuration of the set of PRACH formats F1 and F2 and the corresponding PRACH resources in SIB2. After that, the WTRU may receive GC-DCI indicating cancelled UL resources. Next, there may be overlap with the PRACH resources corresponding to PRACH format F1. If there is no overlap, the WTRU may transmit PRACH with

format F1, on the corresponding PRACH resources. If there is overlap, the WTRU may transmit PRACH using format F2 on the corresponding PRACH resources.

[0245] In one example, the PRACH resources for format F2 or the default Format 0 may be configured as a fixed subset of PRACH resources assigned for format F1. In another example, the resources for format F2 or the default Format 0 may be determined by the WTRU, based on the PRACH resources configured for format F1, and the cancelled uplink resources indicated by UL cancellation indication. For example, the WTRU may be configured by PRACH format 1 which is associated with time resources of length 3 ms. Inside each PRACH resource of length 3 ms there are 3 possible time resource for PRACH format 0 which has time resource of length 1 ms. If the WTRU receives the UL cancellation indication and observes overlap with its own configured PRACH resources (associated with format 1), it switches to PRACH with the default format 0, and selects the first, second or third millisecond of its configured PRACH resource as its effective PRACH resource with format 0, based on the first one that does not overlap with the cancelled UL resources.

[0246] Methods for providing a cross-carrier cancellation indication are provided herein. For an eMBB WTRU transmitting uplink data or UCI on a TDD carrier, a timely cancellation indication may be received on a different component carrier. In one method, the WTRU may cancel a transmission on a given carrier upon receiving a cross carrier cancellation indication. The cross-carrier indication may provide any information necessary. For example, the proposed cross-carrier indication may provide the aforementioned contents of the cancellation indication for a single carrier. For example, the proposed cross-carrier indication may provide the carrier index applicable for cancellation.

[0247] In another example, the proposed cross-carrier indication may provide a timing offset, which can be explicitly signaled or implicitly determined by the WTRU based on downlink reference timings and/or uplink timing advances of both carriers. For example, the WTRU may determine the timing of cancellation considering a timing offset with respect to the time of receiving the cross-carrier indication. In one example, two carriers may have two reference rasters or reference start times. The WTRU may add the difference between the two rasters and/or uplink timing advances, prior to determining the applicable active resource for cancellation on the indicated carrier. In one example, if the WTRU is configured to start a certain timer upon receiving the cancellation indication on the same carrier, the WTRU may delay starting such timer by the time offset if the cancellation indication is a cross-carrier indication. In another example, the WTRU may subtract the timing offset from the initial timer value prior to starting the timer, if the cancellation indication is a cross-carrier indication.

[0248] In another example, the proposed cross-carrier indication may provide an indication for the WTRU to determine whether the cancellation is applicable to the same carrier on which the cancellation indication is received or a different carrier.

[0249] The WTRU may monitor the PDCCH for the cross-carrier indication on the GC-PDCCH or a WTRU specific PDCCH. The carrier index applicable for cancellation may be indicated to the WTRU in a number of ways.

[0250] For example, the carrier index applicable for cancellation may be indicated to the WTRU explicitly. The index of the component carrier may be explicitly indicated. In one example, the WTRU is configured by RRC with a subset of component carriers applicable for inter-WTRU cancellation. The UE may receive a DCI indicating one of the carriers configured by RRC for inter-WTRU cancellation. The WTRU may determine a codebook to map carriers applicable for inter-WTRU cancellation to DCI entries. For example, if the RRC configures the WTRU with 6 carriers as applicable for inter-WTRU cancellation, the WTRU may determine a codebook of 3 bits to determine the carrier index. Alternatively, the WTRU may decode the applicable carrier from a bitmap indicated in the DCI, which indicates which carrier(s) are applicable for cancellation.

[0251] For example, the carrier index applicable for cancellation may be indicated to the WTRU implicitly based on a property of the PDCCH. For example, the WTRU may determine the index of a component carrier applicable for cancellation based on a property of the PDCCH on which the cross-carrier cancellation indication is received, including but not limited to: PDCCH resource, coreset(s), search spaces(s), PDCCH periodicity, DCI format, and/or RNTI used to decode the PDCCH. In one example, the WTRU may be configured by RRC with a subset of component carriers applicable for inter-WTRU cancellation. The WTRU may be further configured by RRC with a mapping table between component carriers and PDCCH properties (e.g. coresets or PDCCH resources). The WTRU may determine the component carrier index for which the cancellation indication is applicable from the coreset on which the cross-carrier indication is received.

[0252] For example, the carrier index applicable for cancellation may be indicated to the WTRU implicitly based on a 1-to-1 carrier mapping. For example, the WTRU may determine the index of the component carrier applicable for cancellation from the carrier index on which the cross-carrier indication is received. The WTRU may further monitor the cancellation indication on a given carrier as a function of the carrier index on which the transmission is scheduled. For example, the WTRU may be configured by RRC with a mapping between CC x and CC y, such that any indication received on CC x implies it is applicable to CC y (possibly in addition to CC x itself). For an eMBB WTRU scheduled on CC y, the WTRU may monitor the PDCCH for a cross carrier indication on CC x.

[0253] Methods for Orthogonal DMRS transmission to enable MMSE-SIC support in power based multiplexing and methods to ensure DMRS orthogonality in Power-based inter-UE multiplexing and prioritization are disclosed herein.

[0254] In one solution, the eMBB WTRU may be configured with possible set of URLLC WTRU DMRS transmission locations and the eMBB UE may: skip transmitting in these specific resources; or transmit an orthogonal DMRS of its own in these resources.

[0255] These pre-defined locations may be one of the following: semi-statically configured and signaled to either or both of the eMBB WTRUs and URLLC WTRUs; semi-statically configured and dynamically signaled to either or both of the eMBB WTRUs and URLLC WTRUs; or dynamically configured and signaled to either or both of the eMBB WTRUs and URLLC WTRUs.

[0256] FIG. 17 illustrates the case where there is no interruption and the eMBB WTRU transmits for the entire duration it is scheduled for.

[0257] FIG. 18 illustrates the case where there is interruption and the eMBB WTRU skips transmitting in the resource occupied by the URLLC WTRU.

[0258] The power levels of the DMRS of both the URLLC WTRU may be boosted to improve the channel estimate of the URLLC UE in the presence of an interferer. An eMBB WTRU may dynamically pause its own transmission when the URLLC UE transmits its DMRS only and then resume transmission of its own data. The eMBB WTRU may interrupt its transmission to transmit an additional DMRS at the same time as in the same resources at the URLLC transmits its DMRS then resume transmission of its own data. In both cases, the gNB is able to estimate a clean channel for an advanced interference cancellation receiver e.g. a successive interference cancellation receiver. The DMRS transmitted by both WTRUs may be configured to occupy the same time-frequency resources but be orthogonal in the code domain e.g., by an orthogonal cover code. As the URLLC WTRU may typically use a front-loaded DMRS, the new DMRS transmitted by the eMBB WTRU may be the first resource allocated to the URLLC. The eMBB WTRU may then resume transmission of its data preventing the issue of a phase discontinuity in its transmission.

[0259] To enable the eMBB WTRU as to when to make the switch, the eMBB WTRU may receive a “cancellation or multiplexing indication” that indicates the resource to replace and possibly the parameters to use for the DMRS (DMRS configuration). The DMRS configuration may be semi-statically configured.

[0260] In the case that the eMBB WTRU may have a 2nd DMRS configured to transmit in the overlapped resources, one of the following may occur:

[0261] The eMBB WTRU may transmit its second DMRS. The URLLC may transmit an additional orthogonal DMRS in these resources.

[0262] The eMBB WTRU may skip transmitting its second DMRS as it has transmitted an additional DMRS in the resource used by the URLLC WTRU for its front loaded DMRS.

[0263] FIG. 19 illustrates eMBB transmission with interruption. eMBB transmits preemptive DMRS that is orthogonal to the URLLC transmission. eMBB has 2nd DMRS and URLLC may transmit 2nd DMRS orthogonal to the 2nd eMBB DMRS.

[0264] The URLLC WTRU procedure is as follows. The URLLC WTRU may receive a DCI instructing it to transmit at a desired resource. The DCI may include a DMRS configuration that ensures orthogonal transmission to any eMBB WTRU DMRS. The URLLC WTRU may transmit data and DMRS that uses the received configuration. The data may be rate matched around all transmitted DMRS. The data may be punctured to accommodate any transmitted DMRS. The data may be rate matched around any URLLC DMRS and punctured to accommodate any eMBB DMRS.

[0265] The eMBB WTRU procedure is as follows. The eMBB WTRU may be configured to monitor for a “cancellation or multiplexing indication” that indicates the resource to replace and possibly the parameters to use for the DMRS (DMRS configuration). This may be configured to occur when the WTRU is scheduled. This may be configured to occur for resources in which the WTRU may be interrupted by a URLLC WTRU, e.g., a preconfigured resource for dynamic URLLC transmission, a preconfigured resource(s) for configured grant URLLC transmission. On reception of a valid multiplexing indication, the eMBB WTRU may modify its current transmission to accommodate the DMRS of the URLLC WTRU. The eMBB WTRU may interrupt its transmission to transmit a DMRS that is orthogonal to the DMRS that the URLLC WTRU can transmit. The eMBB WTRU may interrupt its transmission and not transmit any information in the DMRS resource of the URLLC WTRU. The eMBB WTRU may resume transmission of its data.

[0266] Methods for efficient monitoring in URLLC/eMBB multiplexing are also disclosed. GC-PDCCH signaling is based on a set of WTRUs decoding the PDCCH with a type of RNTI e.g. x-RNTI. This enables the WTRU to receive (e.g., group common) signaling relating to a deterministic set of WTRUs. In the case that there is inter-WTRU multiplexing of both URLLC and eMBB WTRUs, there may be a need to define methods that enables the UE to receive (e.g., group common) signaling relating to a portion of the resource grid (e.g., time/frequency resources in a given bandwidth / BWP / cell). In one example, a URLLC WTRU that is transmitting using a configured grant may have pre-defined resources it needs to transmit in. As such, any

WTRU that transmits in this portion of the grid may need to monitor for cancellation or power control (or a combination) of signaling when it is allocated resources in this portion of the resource grid.

[0267] The gNB may predefine a monitoring configuration for a particular WTRU for a set of resources. In the case of a dynamically scheduled eMBB WTRU, the gNB may include an activation signal for one or more of the configurations that need to be monitored in the scheduling DCI. In the case of a configured grant eMBB WTRU, the gNB may use WTRU specific PDCCH signaling based activation/deactivation. For Type 2 CG, this may be part of the activation/deactivation signaling used to start/stop the CG transmission or separate activation/deactivation signaling to allow for flexibility. For Type 1 CG, this may be new activation / deactivation signaling to enable it know the resources within which it modifies its behavior.

[0268] Methods that enable the WTRU to autonomously determine whether or not the (e.g., group common) signaling is applicable to one or more of its transmissions for a given period – as opposed to blindly follow received signaling are needed. In one possible scheduler strategy for large bandwidths, the network may partition the PRB grid in a number of parts (possibly as a function of target transmission rates for different WTRUs, etc.), then schedule eMBB transmissions to maximize capacity while ensuring that collision in between URLLC transmissions cannot occur. In such a case, signaling could be issued to all WTRUs in a cell which would apply per partition such that the scheduler could control collision between eMBB, URLLC but also power / interference levels etc. This would factor out the “unpredictable” timing aspects of URLLC with respect to eMBB scheduling – when the NW schedules a URLLC transmission, it issues a common DCI pre-emption indication for the portion of the spectrum corresponding to the URLLC transmission, thus making all eMBB WTRUs adjust accordingly if and only if those WTRUs determine that they are scheduled /active in transmission for that spectrum partition. The network could configure one RNTI per partition for such DCI control information. Such control information could include pre-emption indication for the partition at least in time (maybe also in frequency), a power backoff for the partition at least in time (maybe also in frequency), an indication to mute transmissions on specific resources (e.g., for DM-RS of URLLC transmissions) at least in time (maybe also in frequency). In this manner, the gNB does not need to (re-)configure WTRUs in terms of grouping as RNTIs relate to spectrum partitions and WTRU's would autonomously decode for the proper RNTI as a function of the resources associated with a (scheduled) transmission and only if the control information could change / impact how the WTRU would perform the transmission (e.g., if pre-emption could be applied, etc.).

[0269] For example, the WTRU could autonomously determine that it should decode for a given RNTI for a DCI for pre-emption indication as a function of the portion of the bandwidth in which the WTRU has a

scheduled transmission, for a period during which it may expect such signaling (e.g., before and/or during the transmission(s)) if the transmission is for a low priority (i.e., not URLLC).

[0270] A generalized procedure is discussed in the following. WTRU given behavior [A] may be a function of at least one of the follow. Whether or not they have a transmission [TRx] scheduled within a period of time [x], otherwise the WTRU does not perform [A] for the period [y]. For example, the WTRU may evaluate conditions for [A] if [TRx] at least partly overlap with [x] in time.

[0271] The associated priority Po [e.g., 0-URLLC-high priority / 1-eMBB-low priority] of such transmission [TRx]. For example, the WTRU may evaluate conditions for [A] if [Po] corresponds to [1-eMBB], otherwise the WTRU does not perform [A] for the period [y], where [TRx] may be characterized by a resource allocation in time (start, and/or duration) / frequency (e.g., PRBs), by a type of scheduling information [configured, or from reception of DCI], by a MCS table, by a (set of) MCS value(s), by a given power level, by a HARQ status (e.g., initial, or retransmission), a priority (e.g., of the data included in the transport block);

[0272] Where [y] may correspond to at least one of the following. A period (possibly offset time) before the start of TRx, where the offset in time may be a configuration aspect of the WTRU. A period corresponding to the transmission duration of TRx, where [A] may correspond to at least one of the following:

[0273] The WTRU determines one (or more) blind decoding parameters, including at least one of:

[0274] The RNTI(s) to monitor. For example, the WTRU may monitor a RNTI that corresponds (e.g., by configuration) to a specific set of PRBs, if such set of PRB is a superset of at least some of the resources scheduled for [TRx], the search space (SS) to monitor. For example, similar as above with SS instead of RNTI, the Aggregation Level (AL) to monitor. For example, similar as above with AL instead of RNTI, the DCI format(s) / size(s) to monitor. For example, similar as above with DCI format(s) / size(s) instead of RNTI and the PDCCH monitoring occasions. For example, similar to the above with PDCH occasions instead of RNTI.

[0275] The WTRU may determine that it should apply received signaling, e.g., a pre-emption notification; For example, the WTRU applies the pre-emption if it determines that the indication corresponds to a superset of at least some of the resources scheduled for [TRx].

[0276] The WTRU determines that it should apply a power compensation / reduction. For example, similar as above with power compensation instead of pre-emption.

[0277] The WTRU determines that it should refrain from performing transmission in specific symbols / resources e.g., for DM-RS skipping. For example, similar as above with DM-RS muting instead of pre-emption, where the WTRU uses one or more characteristic of the such transmission to evaluate whether or not to

perform behavior [A], e.g.: Resource allocation for the transmission in frequency and/or time (e.g., set of PRBs). For example, the WTRU may perform [A] if during period [y] if [TRx] may at least partially overlap with period [x] if Po corresponds to 1-eMBB. For example, the WTRU may perform [A] if [TRx] may at least partially overlap with PRBs within a certain part of the frequency band if Po corresponds to 1-eMBB.

[0278] Type of grant (e.g., configured or dynamic) may also be included. For example, the WTRU may perform [A] if during period [y] if [TRx] is scheduled by a configured grant and may at least partially overlap with period [x].

[0279] Whether or not the transmission is the initial transmission or a retransmission may be included. For example, the WTRU may perform [A] if during period [y] if [TRx] may at least partially overlap with period [x] if Po corresponds to 1-eMBB.

[0280] The applicable (set of) MCS may be included. For example, the WTRU may perform [A] if during period [y] if [TRx] may at least partially overlap with period [x] if Po corresponds to 1-eMBB.

[0281] Solutions to avoid or reduce uplink interference may be included. A WTRU may follow certain procedures to prevent or reduce uplink interference. For example, the WTRU may follow at least one of: apply a power compensation or reduction to a transmission, refrain from performing a previously scheduled transmission for at least a portion of the time resources allocated for the transmission, or for specific time symbols or resources (e.g. DM-RS), monitor PDCCH for an indication to apply or not an interference reduction behavior, such as an indication to cancel a transmission, to confirm a transmission, or to reduce transmission power, and perform a previously scheduled transmission in an alternate resource;

[0282] The WTRU may determine whether or how to apply at least one of the above procedures during a first period as a function of at least one of the following: whether or not the WTRU has a transmission scheduled within a second period or overlapping with a second period and at least one characteristic of the transmission, such as: a priority level associated to the transmission, such as corresponding to eMBB or URLLC, a resource allocation for the transmission in frequency and/or time (e.g. set of PRBs), a type of grant (configured type 1, configured type 2 or dynamic), a type of physical channel (PUSCH, PUCCH, PRACH) or physical signal (SRS, DM-RS), a PUCCH format, a type of uplink control information (HARQ-ACK, SR, CSI), a scheduling type for CSI (aperiodic, periodic or semi-persistent) or SRS, whether or not the transmission is the initial transmission or a retransmission (e.g., for PUSCH, SR or PRACH), and a MCS table used for the scheduling of the transmission, or an MCS used for the transmission.

[0283] In the above, the first period may correspond to at least one of a period (possibly offset time) before the start of the transmission, where the offset in time may be a configuration aspect of the WTRU or a period corresponding to the duration of the transmission.

[0284] The WTRU may monitor PDCCH for an indication according to at least one of the following: The WTRU may determine one or more parameters for decoding of PDCCH, including at least one of: at least one search space configuration including a Coreset, periodicity and offset of monitoring occasions, type, aggregation levels, set of DCI formats, etc., a set of RNTI(s) to monitor, at least one of the above aspects may be associated to specific resources defined in time and/or frequency resources for the transmission potentially affected (e.g., cancelled or transmitted with reduced power). An indication received in a specific time instance may affect a transmission overlapping in time with a period defined relative to that time instance (e.g., the same slot or a subsequent slot, plus an offset), a set of time and/or frequency resources may be indicated by a field of DCI of the indication. For example, the DCI may include a bitmap indicating which set of time symbols or which set of time symbols and frequency-domain portions is concerned by the indication.

[0285] For example, the WTRU may autonomously determine that it should decode for a given RNTI for a DCI for cancellation indication as a function of the portion of the bandwidth in which the WTRU has a scheduled transmission, for a period during which it may expect such signaling (e.g., before and/or during the transmission(s)) if the transmission is for a low priority (i.e., not URLLC).

[0286] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

CLAIMS

What is Claimed:

1. A method for use in a wireless transmit/receive unit (WTRU), the method comprising:
a scheduler providing an UL grant or configuration of PUCCH resources for ultra-reliable low-latency communications (URLLC) WTRU that overlap in time-frequency resources that are assigned for UL transmission by eMBB UEs.
2. A method for use in a wireless communication system, the method comprising: performing eMBB UE cancellation and URLLC UE pre-emption with cancellation/scheduling indication decoding failure.
3. A method for use in a wireless transmit/receive unit (WTRU), the method comprising:
receiving signaling related to PUSCH cancellation.
4. A method for use in a wireless communication system, the method comprising:
performing a selection procedure of power control and transmission parameters by an interrupting WTRU.
5. A method for use in a wireless communication system, the method comprising:
performing PRACH cancellation or modification in order to multiplex or prioritize UL transmissions from UEs in multiple modes.
6. A wireless transmit/receive unit (WTRU) configured to perform at least part of the method of any one of the proceeding claims.
7. The WTRU of claim 6 wherein the WTRU is configured for performing URLLC communications.
8. The WTRU of claim 6 wherein the WTRU is configured for performing eMBB communications.
9. A method performed in a Wireless Transmit Receive Unit (WTRU) for adaption of uplink transmission with dynamic grant, the method comprising:

receiving a downlink control information DCI that includes a resource set for an UL dynamic grant;

receiving a GC-DCI that indicates cancelled UL resources;

determining whether the resource set for Uplink overlaps with the cancelled UL resources;

on a condition that resource sets do not overlap, transmitting data on the PUSCH using the dynamic grant on the indicated resource set;

on a condition that resource sets do overlap, determining an active resource set for transmitting data on the PUSCH; and

transmitting data on the PUSCH using the determined active resource set.

10. The method of claim 9 wherein determining an active resource set is based on the dynamic resource set and the cancelled UL resources indicated by GC-DCI.

11. The method of claim 9 wherein the WTRU is configured to perform eMBB communications.

12. The method of claim 9 wherein the WTRU is configured to perform URLLC communications.

13. A wireless transmit/receive unit (WTRU) configured to perform at least part of the method of any one of claims 9-12.

ABSTRACT

Methods and apparatus for uplink (UL) multiplexing and prioritization involving cancellation, interrupts, or preemption of PUCCH, eMBB UE, URLLC UE, PUSCH, and PRACH. Specifically methods are disclosed for performing PUCCH cancellation or modification. Methods are disclosed for eMBB UE cancellation and URLLC UE pre-emption with a cancellation/scheduling indication decoding failure. Methods are also disclosed for signaling of PUSCH cancellation. Methods are also disclosed for a selection procedure of power control and transmission parameters by the interrupting UE. Methods are also disclosed for performing PRACH cancellation or modification.

100

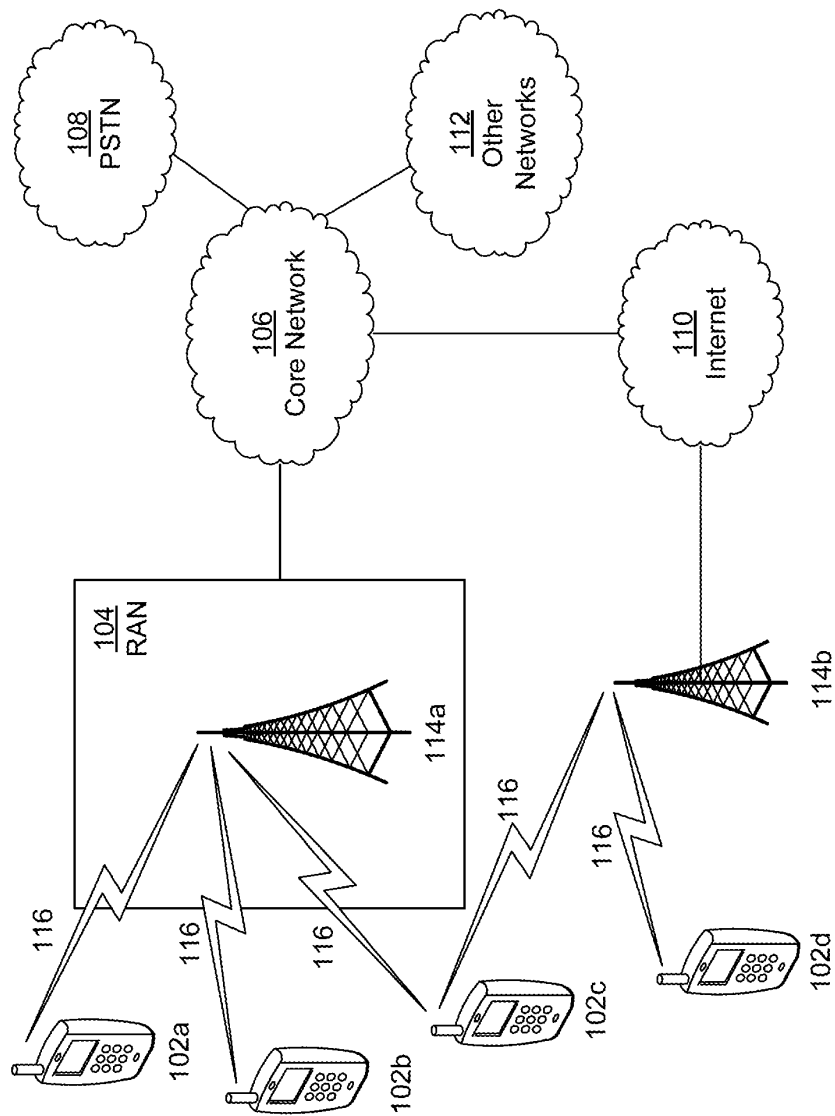


FIG. 1A

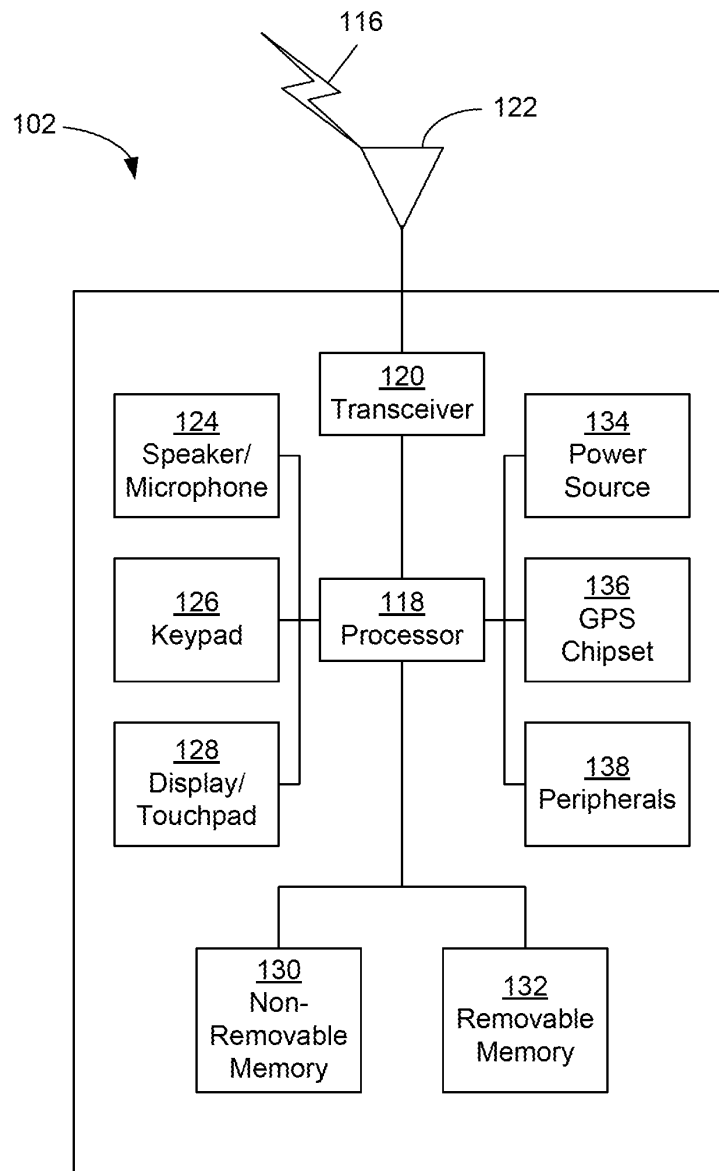


FIG. 1B

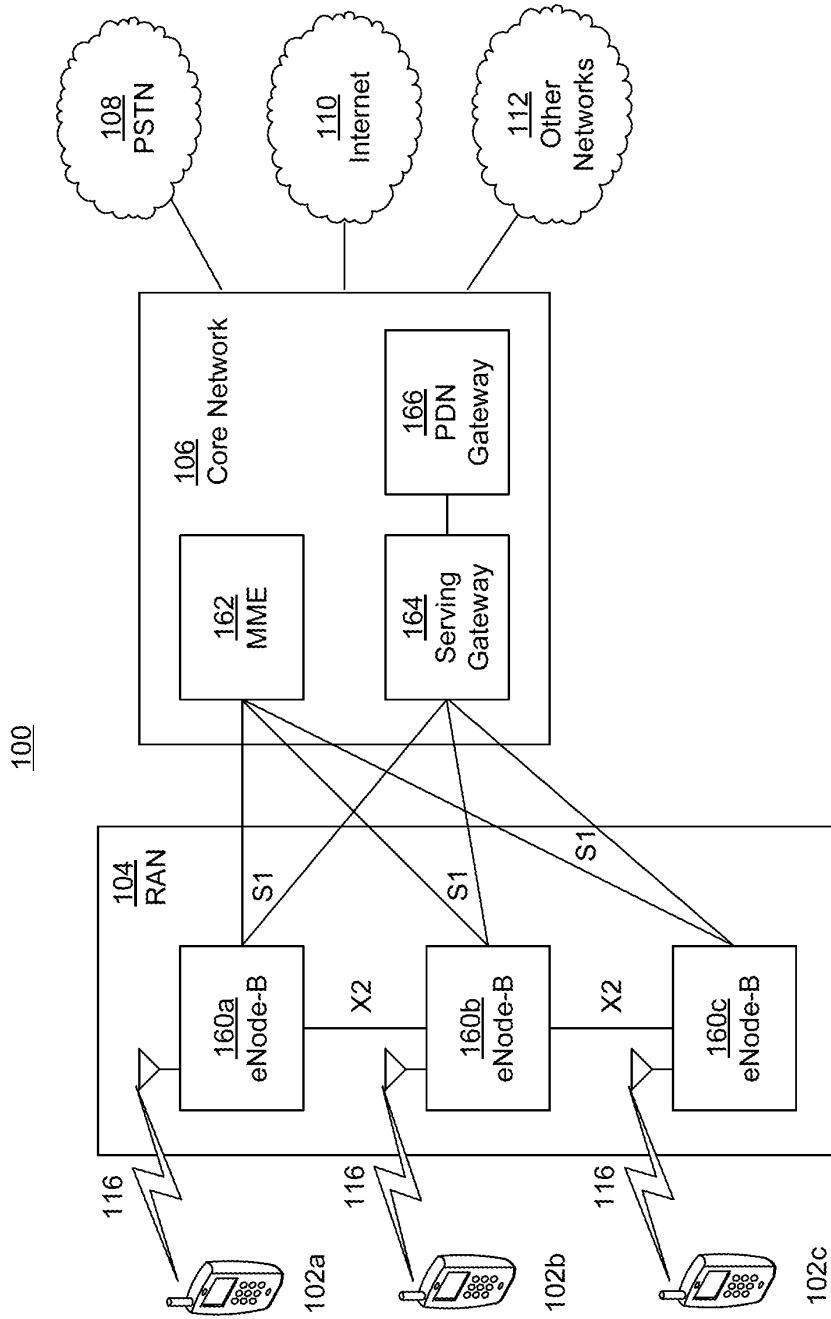


FIG. 1C

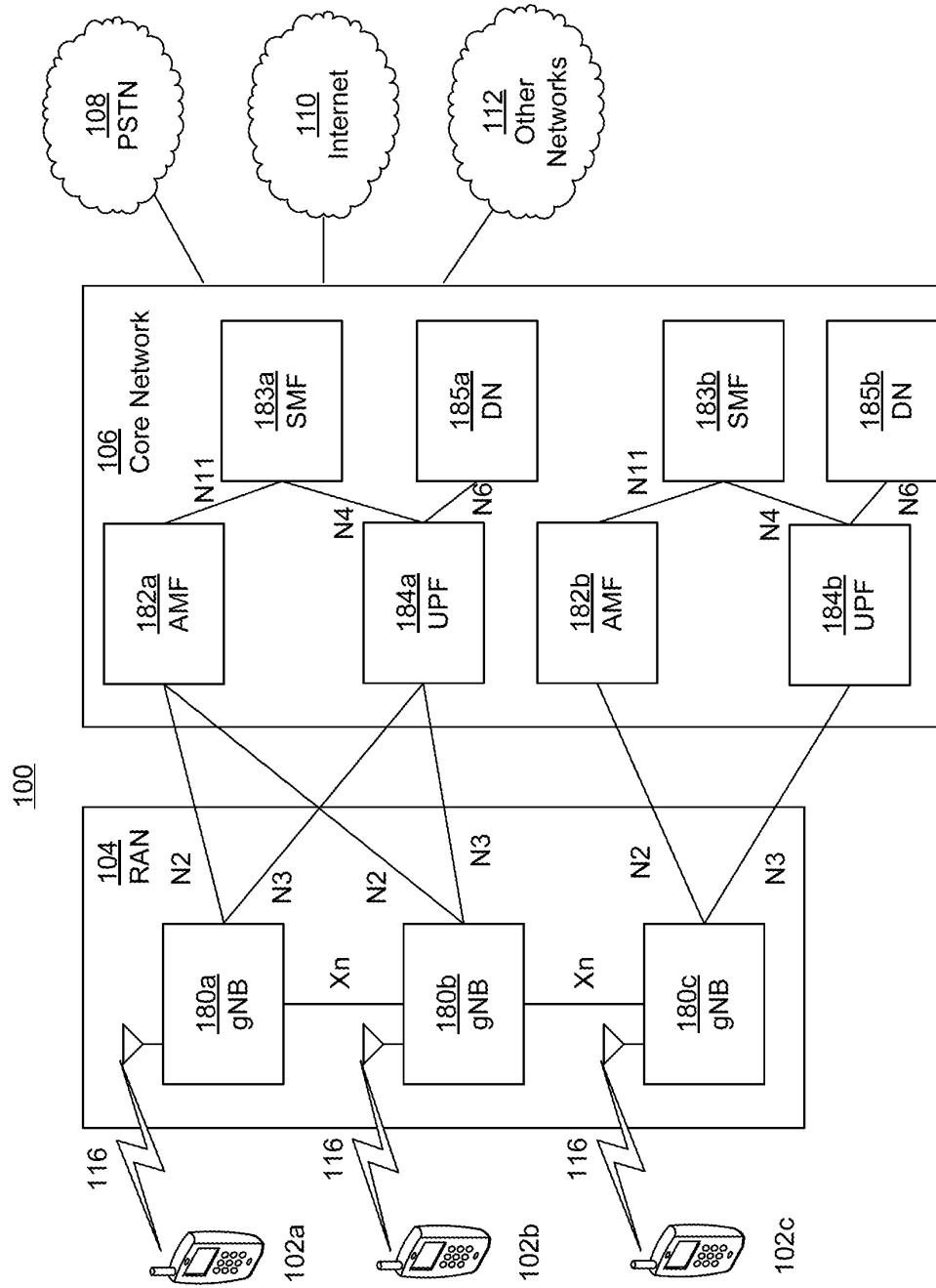


FIG. 1D

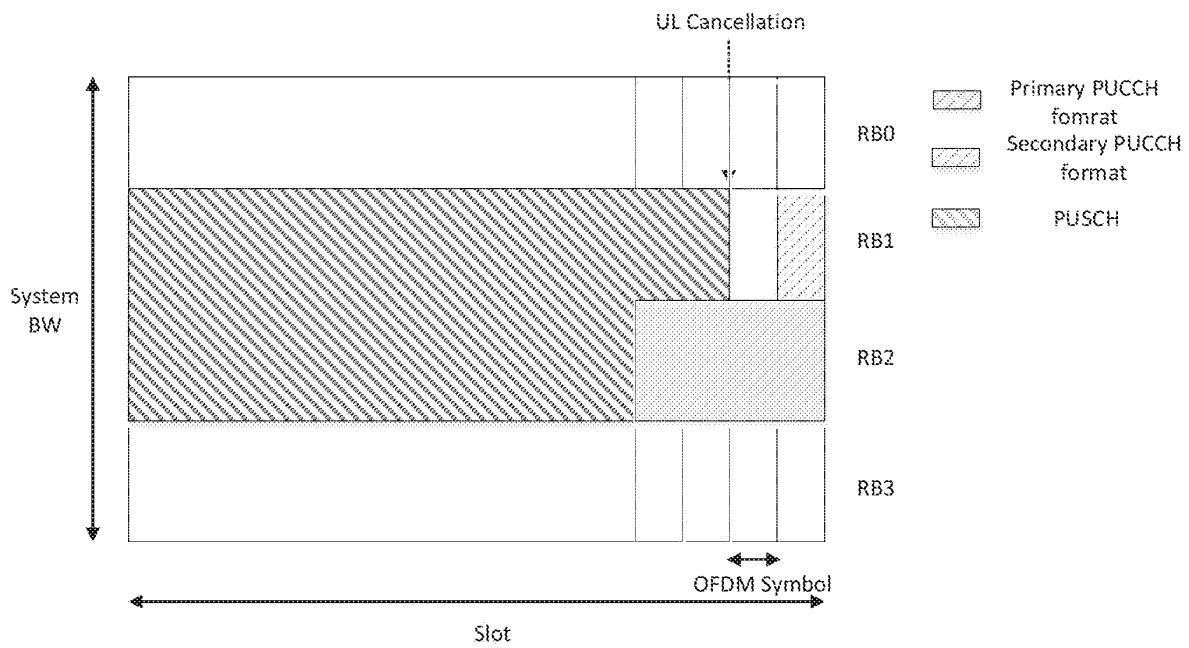


FIG. 2

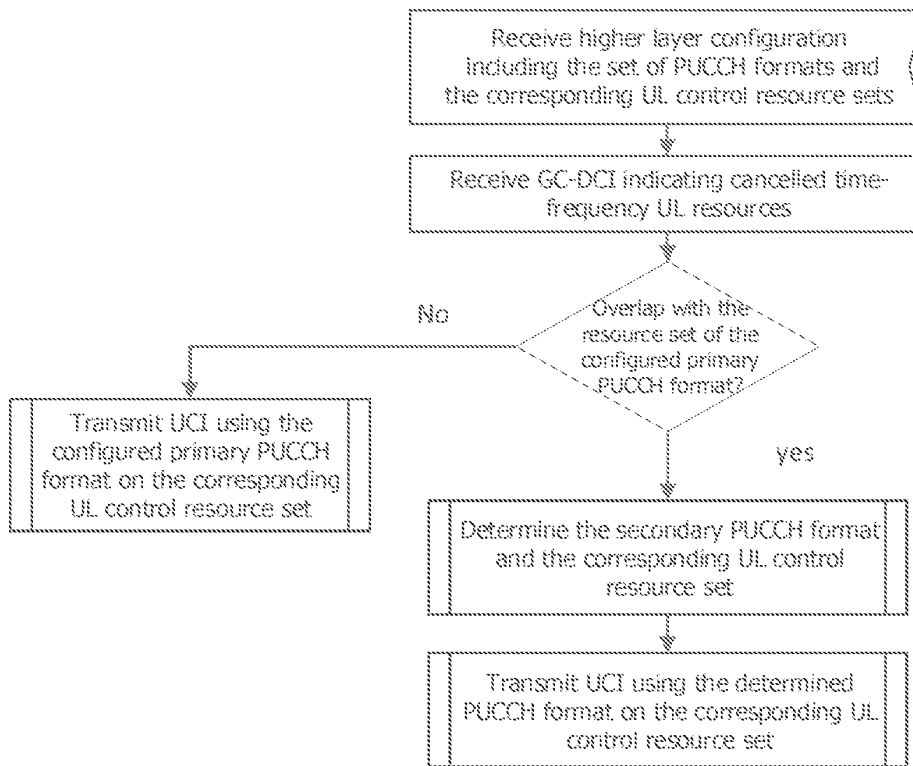


FIG. 3

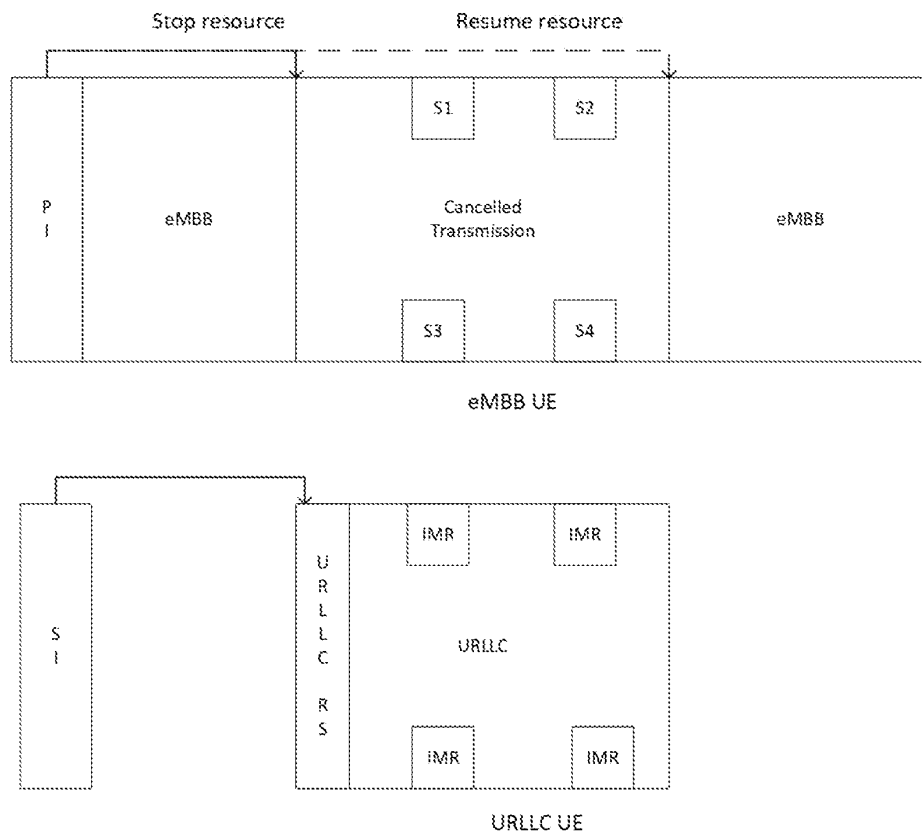


FIG. 4

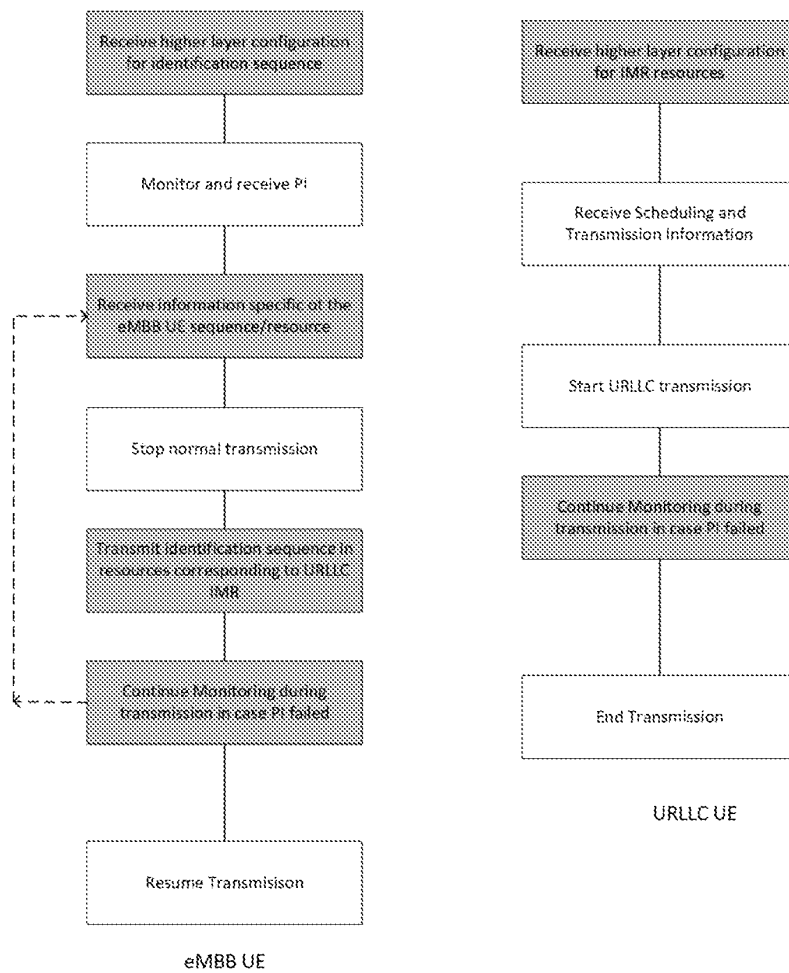


FIG. 5

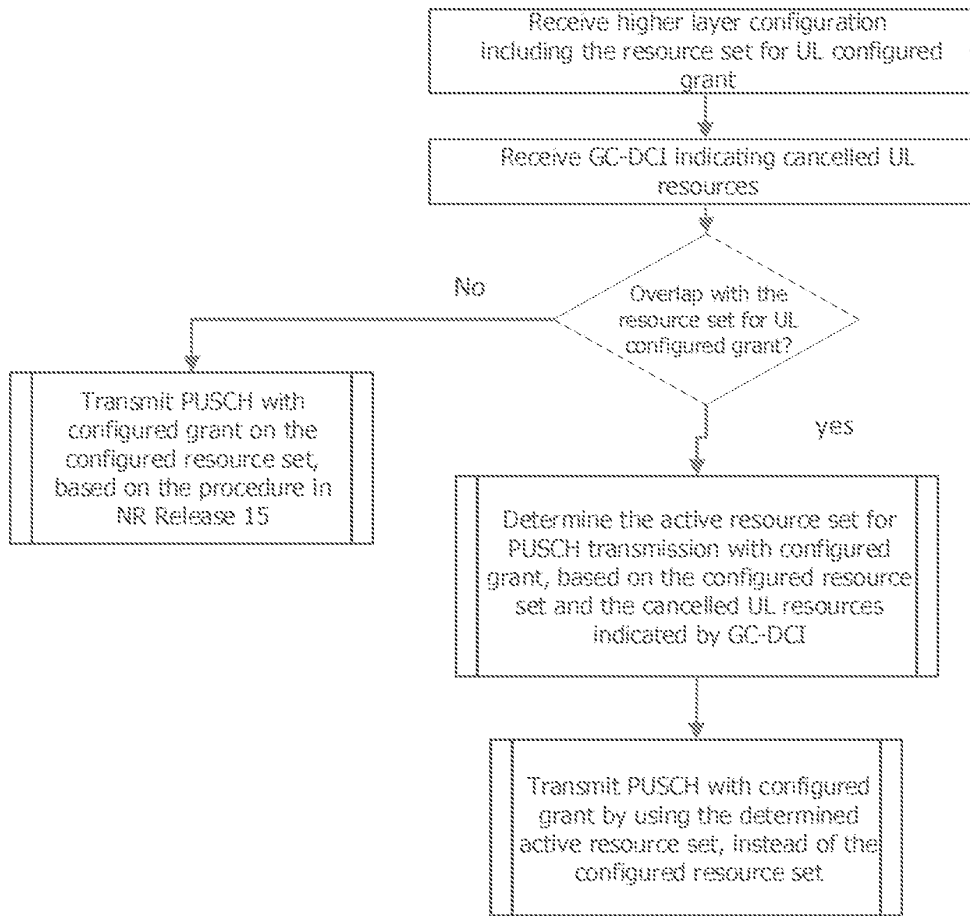


FIG. 6A

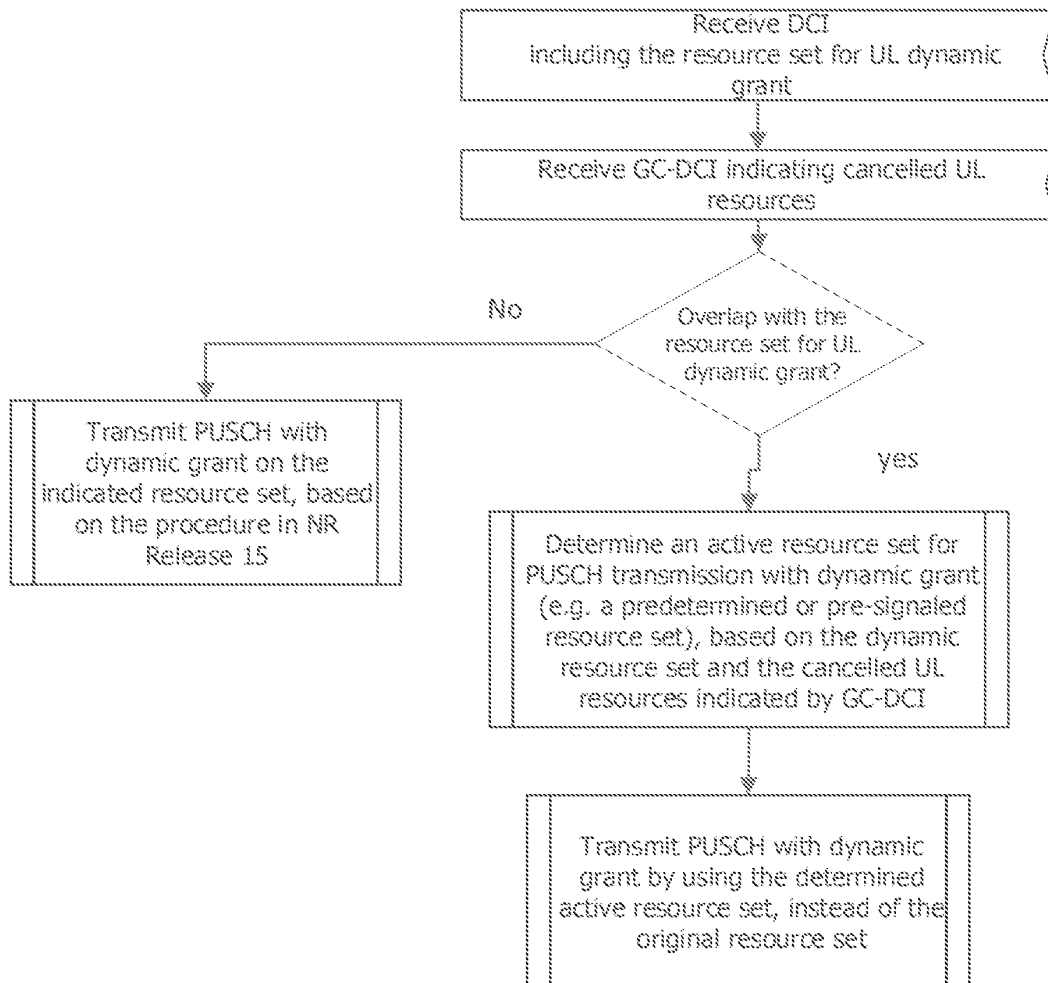


FIG. 6B

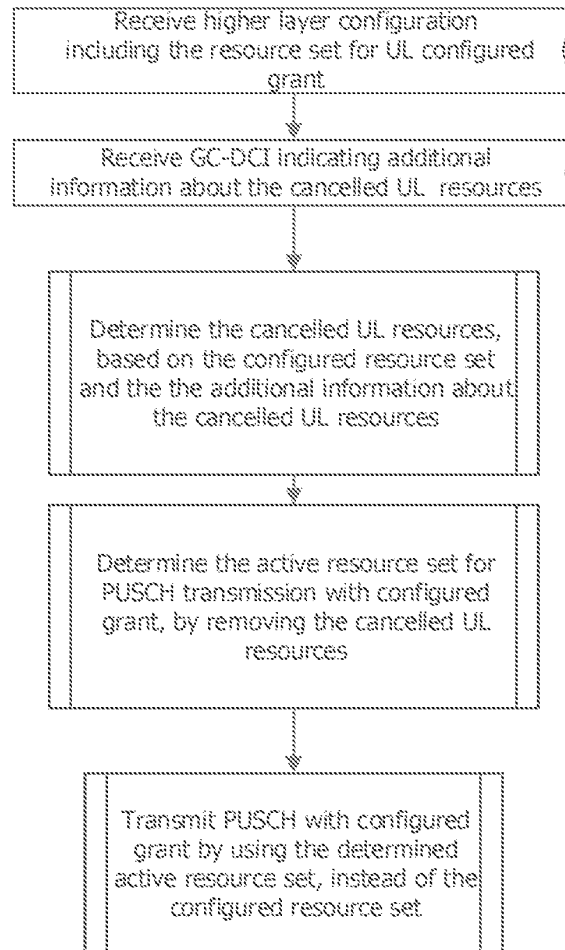


FIG. 7

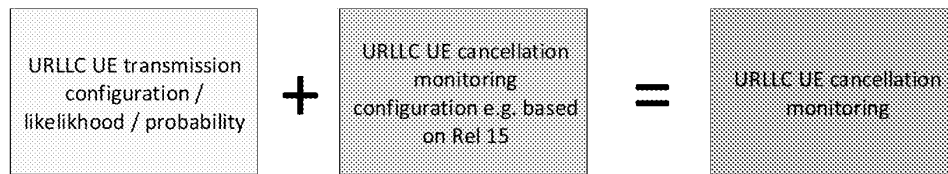


FIG. 8

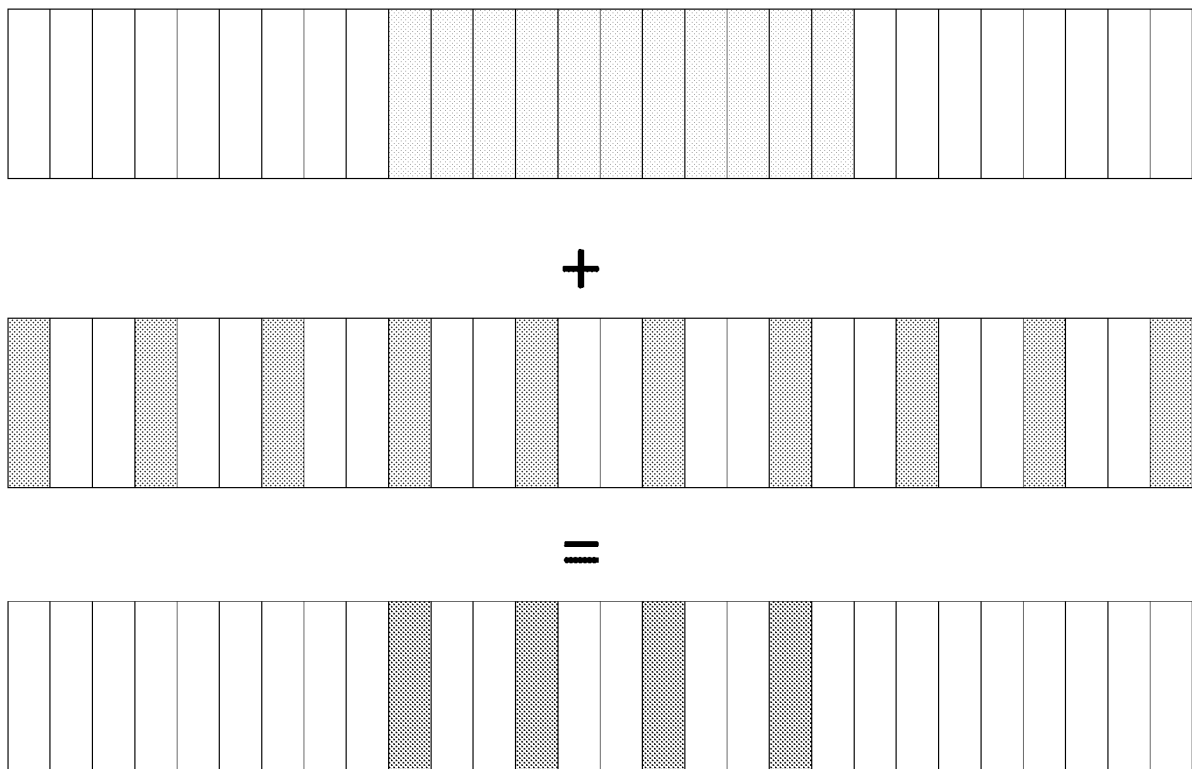


FIG. 9

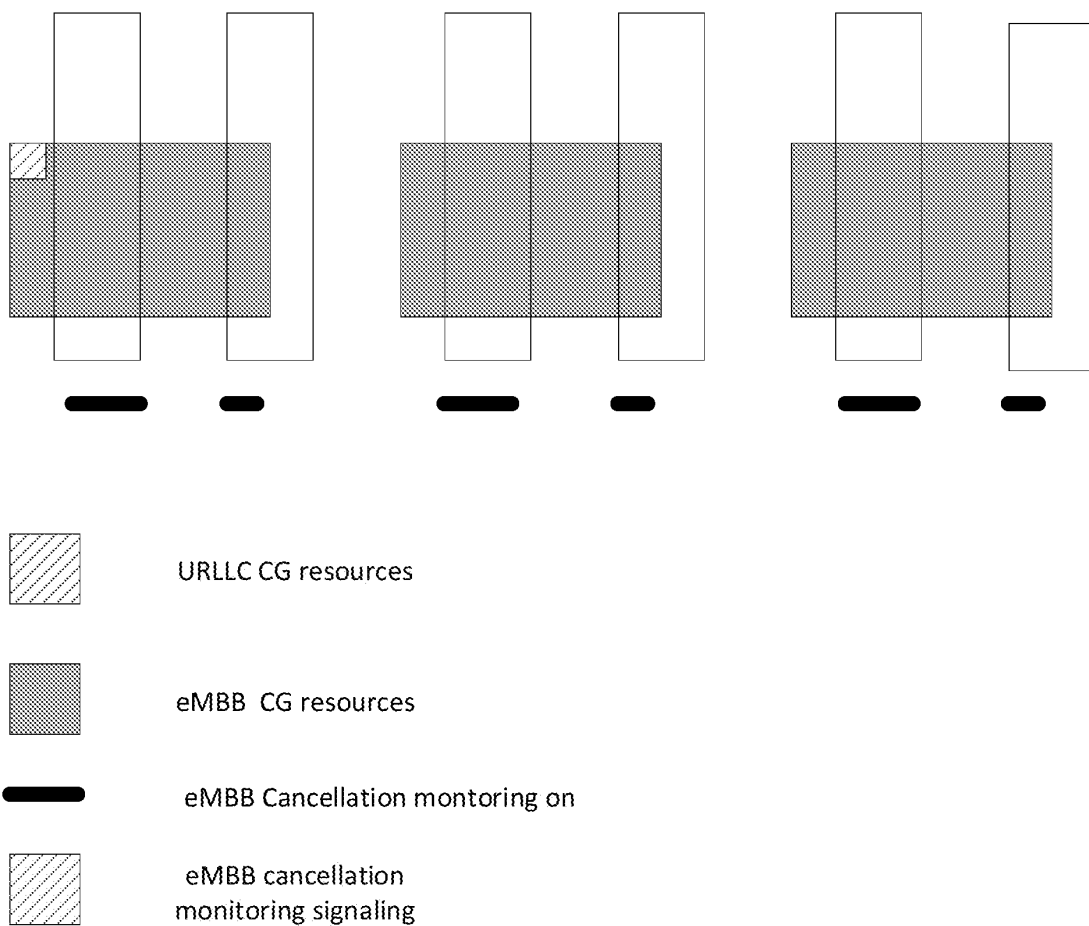


FIG. 10

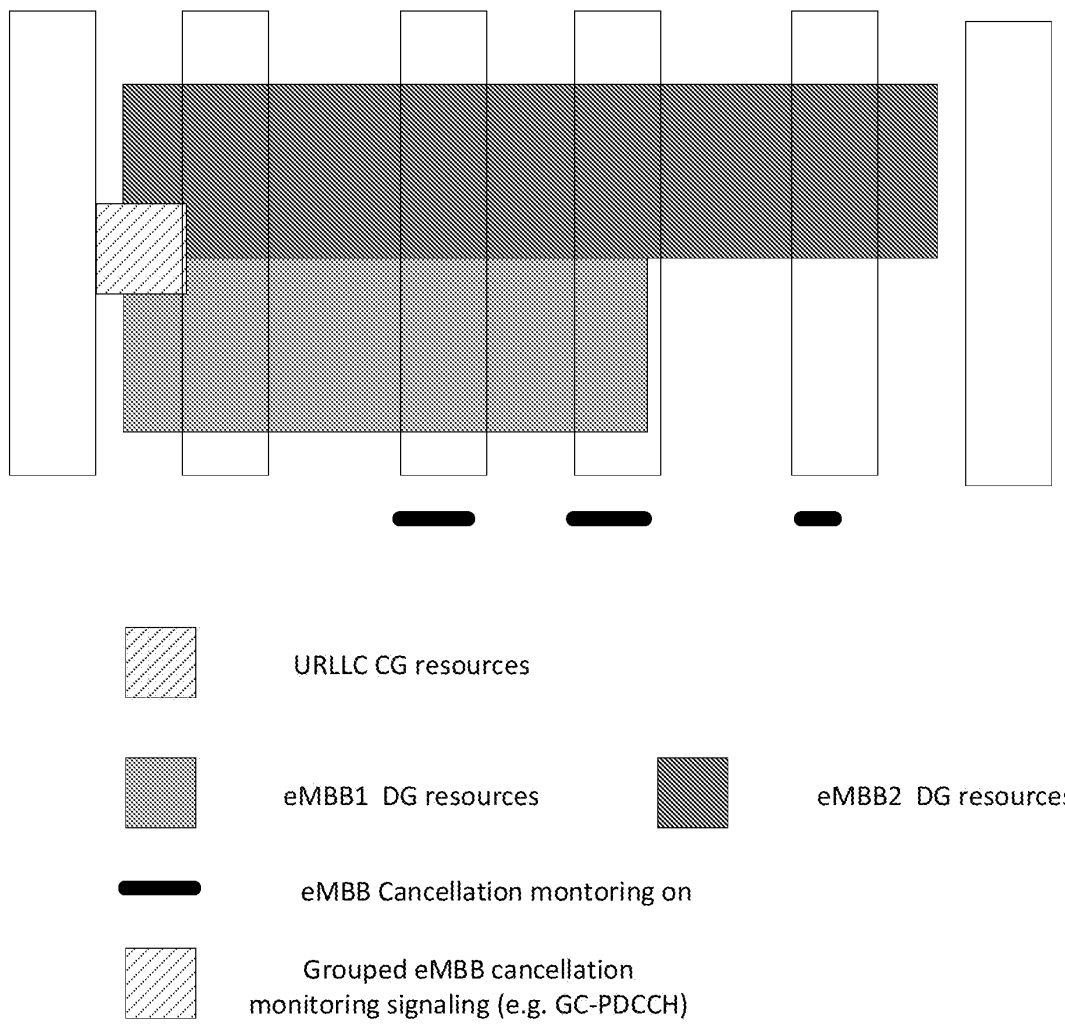


FIG. 11

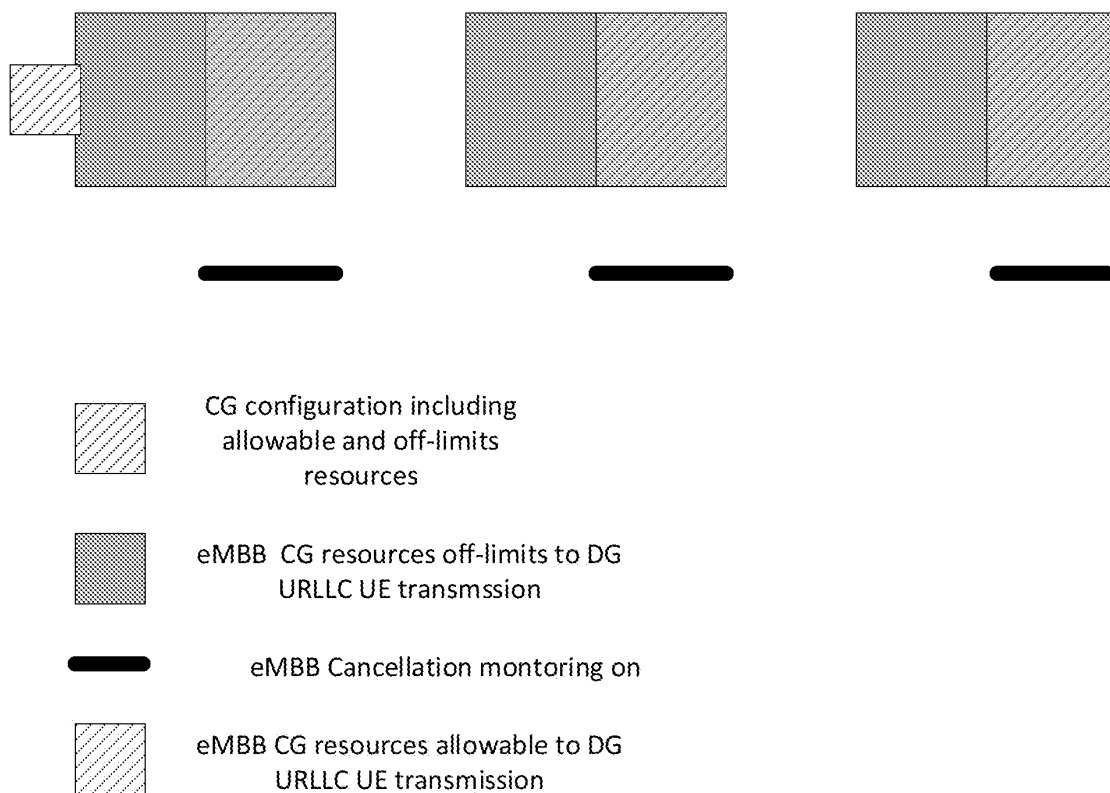


FIG. 12

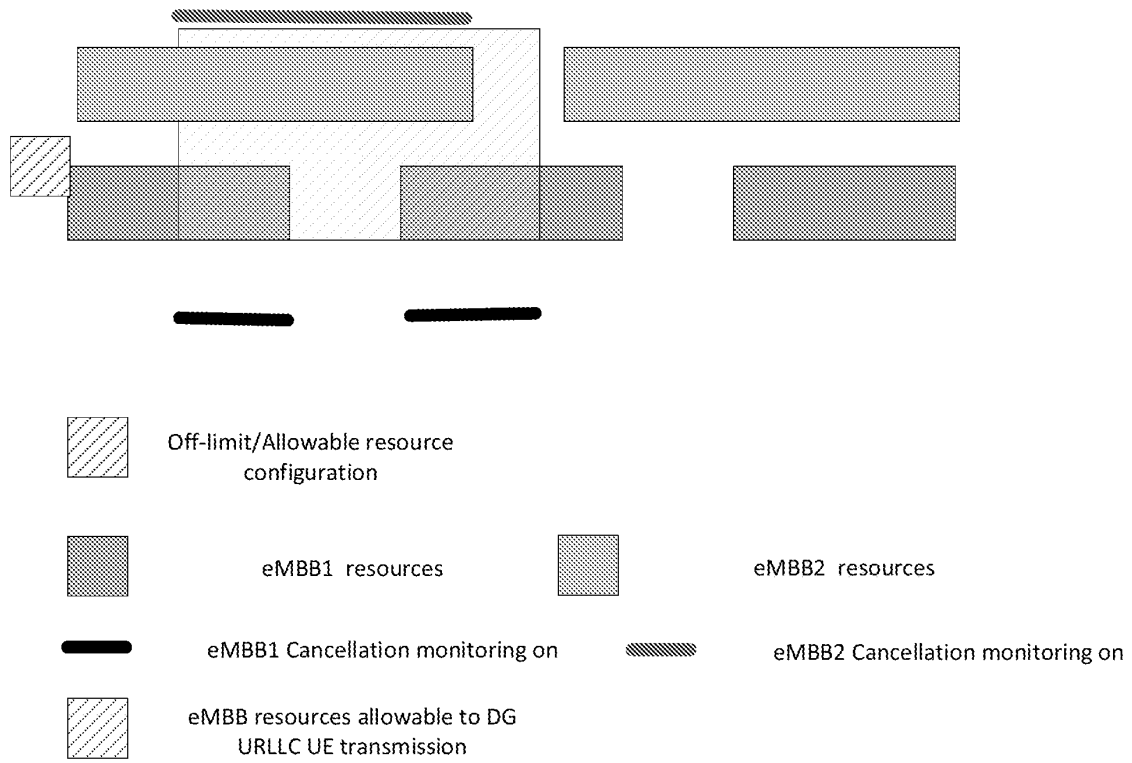


FIG. 13

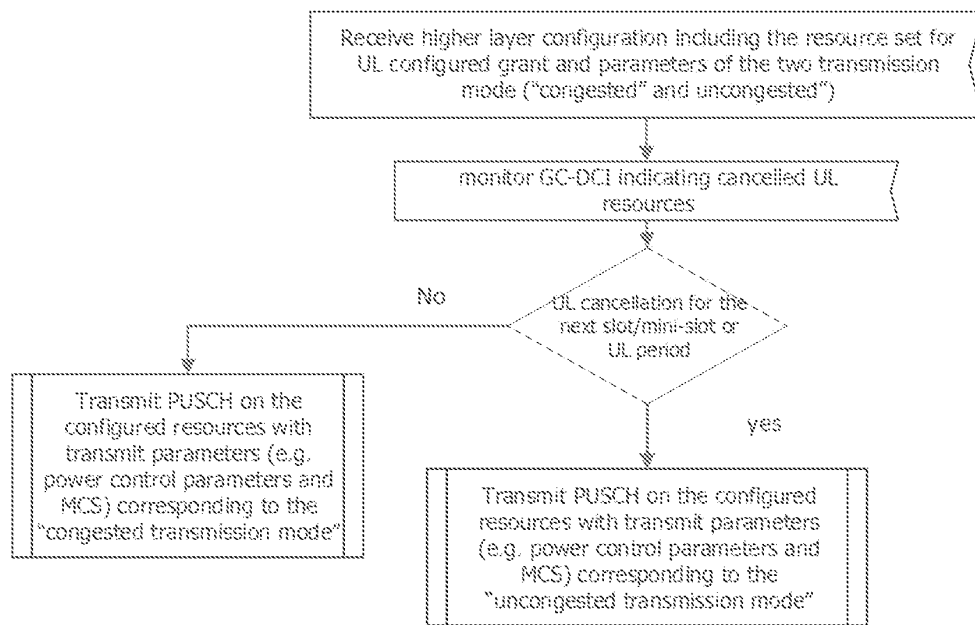


FIG. 14

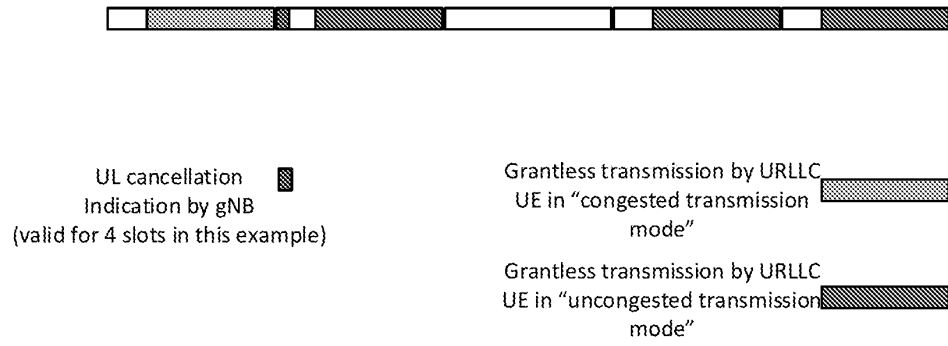


FIG. 15

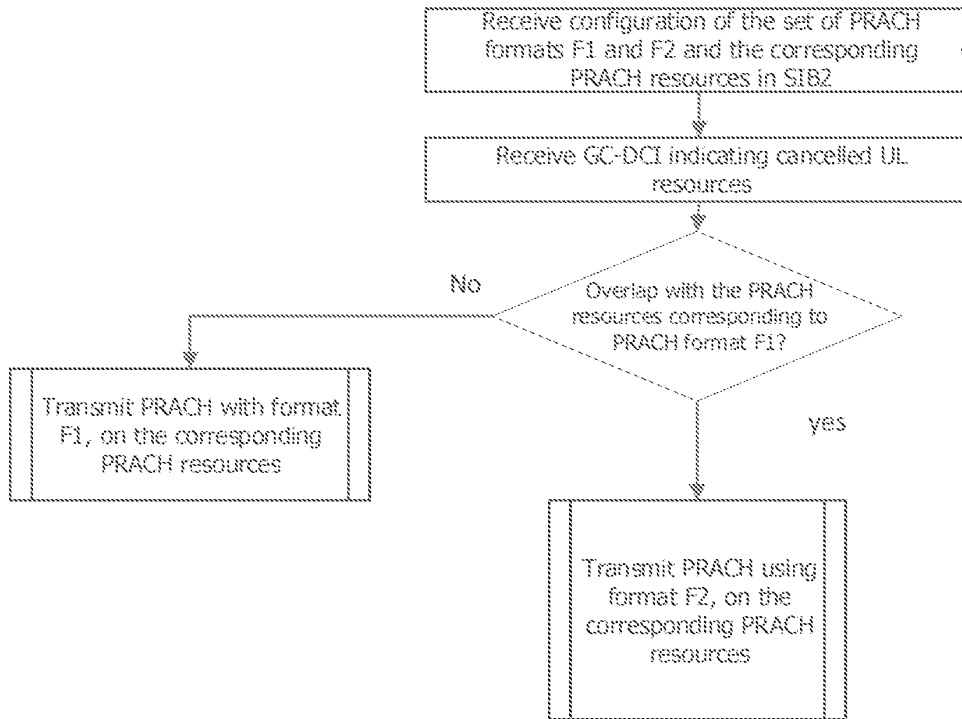
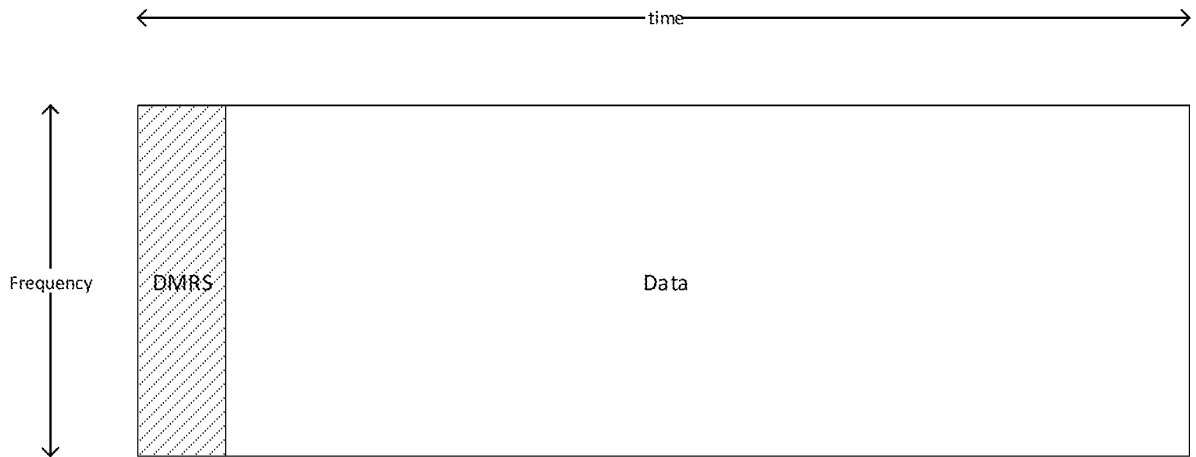
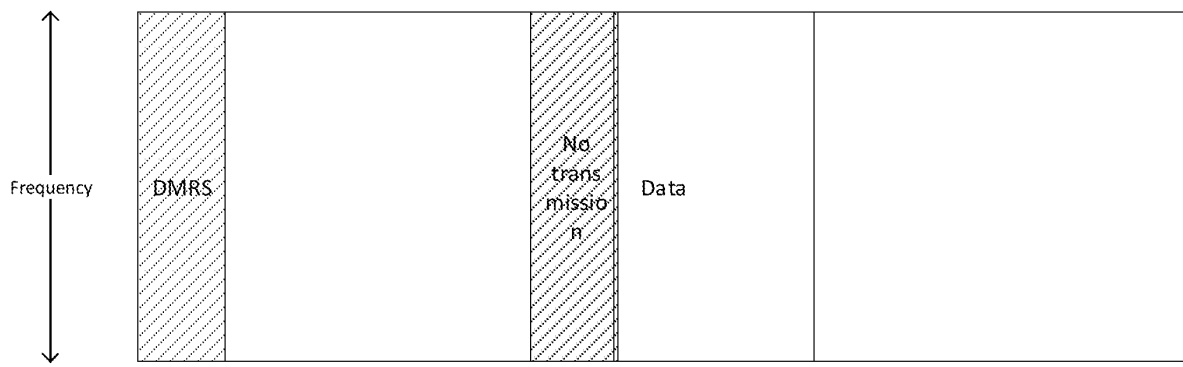


FIG. 16



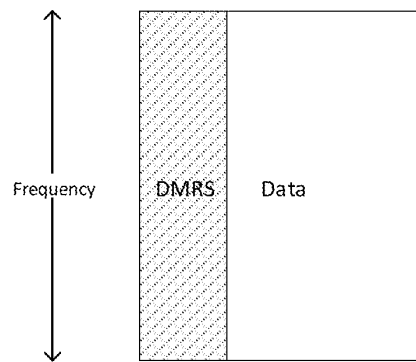
No interruption (eMBB UE)

FIG. 17



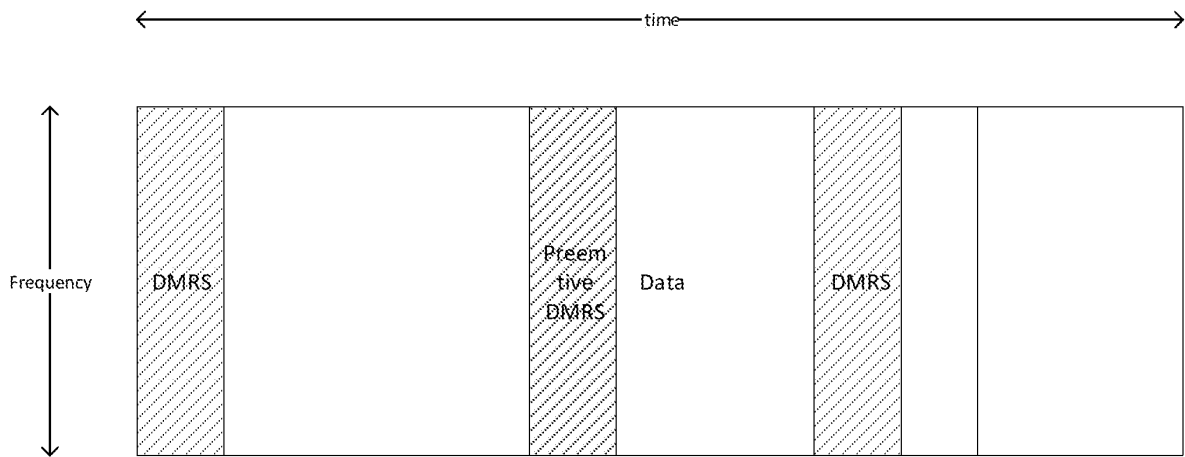
Interruption (eMBB UE)

← time →

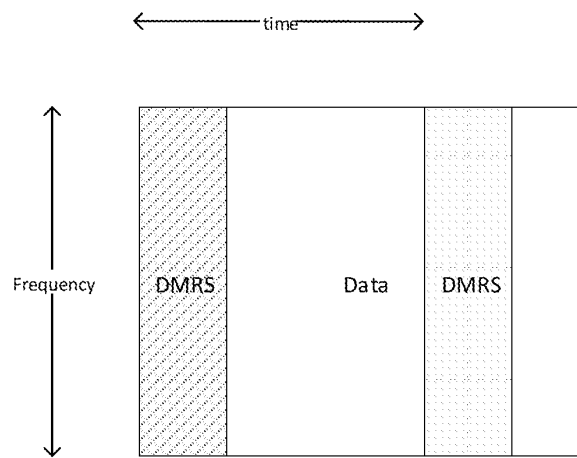


Interruption (URLLC UE)

FIG. 18



Preemption (eMBB UE)



Preemption (URLLC UE)

FIG. 19

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor	1				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Mahmoud		Taherzadeh Boroujeni			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	San Diego	State/Province	CA	Country of Residence	US	
Mailing Address of Inventor:						
Address 1	8840 Costa Verde Blvd. #3126					
Address 2						
City	San Diego	State/Province	CA			
Postal Code	92122	Country	US			
Inventor	2				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Oghenekome		Oteri			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	San Diego	State/Province	CA	Country of Residence	US	
Mailing Address of Inventor:						
Address 1	9276 Scranton Road					
Address 2	Suite 300					
City	San Diego	State/Province	CA			
Postal Code	92121	Country	US			
Inventor	3				Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Shahrokh		Nayeb Nazar			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						

Application Data Sheet 37 CFR 1.76		Attorney Docket Number		IDC-14850US01	
		Application Number			
Title of Invention		METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR			

City	San Diego	State/Province	CA	Country of Residence ⁱ	US
------	-----------	----------------	----	-----------------------------------	----

Mailing Address of Inventor:

Address 1	3489 Overpark Rd.				
Address 2					
City	San Diego	State/Province	CA		
Postal Code	92130	Country ⁱ	US		
Inventor	4				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Faris		Alfarhan		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Montreal	Country of Residence ⁱ	CA		

Mailing Address of Inventor:

Address 1	1000 Sherbrooke Street West				
Address 2	10th Fl.				
City	Montreal	State/Province	QC		
Postal Code	H3A 3G4	Country ⁱ	CA		
Inventor	5				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Paul		Marinier		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Brossard	Country of Residence ⁱ	CA		

Mailing Address of Inventor:

Address 1	1000 Sherbrooke Street West				
Address 2	10th Fl.				
City	Montreal	State/Province	QC		
Postal Code	H3A 3G4	Country ⁱ	CA		
Inventor	6				Remove
Legal Name					
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Ghyslain		Pelletier		

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service			
City	Montreal	Country of Residence ⁱ	CA
Mailing Address of Inventor:			
Address 1	1000 Sherbrooke Street West		
Address 2	10th Fl.		
City	Montreal	State/Province	QC
Postal Code	H3A 3G4	Country ⁱ	CA
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.			Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).			
☐ An Address is being provided for the correspondence information of this application.			
Customer Number	24374		
Email Address	eooffice@vklaw.com	Add Email	Remove Email

Application Information:

Title of the Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		
Attorney Docket Number	IDC-14850US01	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	21	Suggested Figure for Publication (if any)	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.											
<table border="1"> <tr> <td>Please Select One:</td> <td>☒ Customer Number</td> <td>☐ US Patent Practitioner</td> <td>☐ Limited Recognition (37 CFR 11.9)</td> </tr> <tr> <td>Customer Number</td> <td colspan="3">24374</td> </tr> </table>				Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)	Customer Number	24374		
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)								
Customer Number	24374										

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78. When referring to the current application, please leave the "Application Number" field blank.			
Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) ¹ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ^j (if applicable)	Remove
Additional Foreign Priority Data may be generated within this form by selecting the Add button.				Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.			
Applicant	1	Remove	
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.			
		Clear	
Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor	
☐ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest	
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:			
Name of the Deceased or Legally Incapacitated Inventor:			
If the Applicant is an Organization check here. ☒			
Organization Name	DAC HOLDINGS, INC.		
Mailing Address Information For Applicant:			
Address 1	200 Bellevue Parkway		
Address 2	Suite 300		
City	Wilmington	State/Province	DE
Country	US	Postal Code	19809
Phone Number		Fax Number	
Email Address			
Additional Applicant Data may be generated within this form by selecting the Add button. Add			

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

Assignee 1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
				Remove
If the Assignee or Non-Applicant Assignee is an Organization check here.				☐
Prefix	Given Name	Middle Name	Family Name	Suffix
Mailing Address Information For Assignee including Non-Applicant Assignee:				
Address 1				
Address 2				
City		State/Province		
Country i		Postal Code		
Phone Number		Fax Number		
Email Address				
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.				Add

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Todd A. Norton/		Date (YYYY-MM-DD)	2019-08-13
First Name	Todd A.	Last Name	Norton	Registration Number
				48636
Additional Signature may be generated within this form by selecting the Add button.				Add

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	IDC-14850US01
		Application Number	
Title of Invention	METHODS AND APPARATUS FOR UL MULTIPLEXING AND PRIORITIZATION IN NR		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

SCORE Placeholder Sheet for IFW Content

Application Number: 62886173

Document Date: 08/13/2019

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

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