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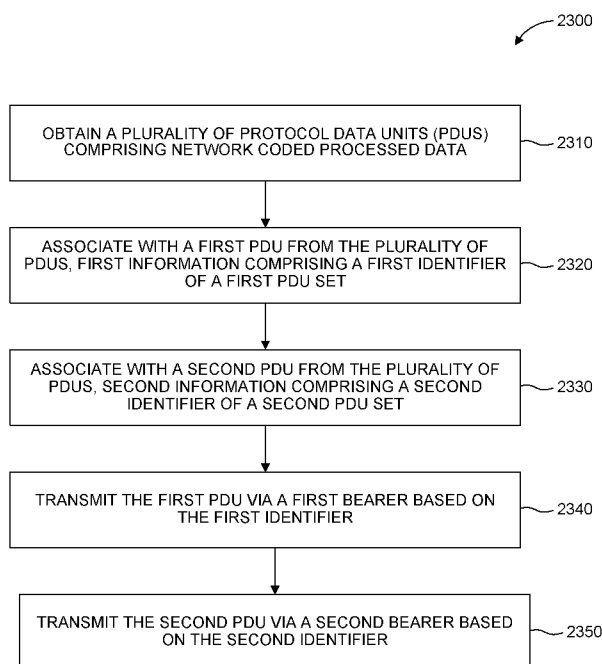


FIG. 23

(57) Abstract: Procedures, methods, architectures, apparatuses, systems, devices, and computer program products comprising a wireless transmit/receive unit (WTRU) configured for obtaining a plurality of protocol data units (PDUs) comprising network coded processed data; associating with a first PDU from the plurality of PDUs, information comprising a first identifier of a first PDU set; associating with a second PDU from the plurality of PDUs, information comprising a second identifier of a second PDU set; transmitting the first PDU via a first bearer based on the first identifier; and transmitting the second PDU via a second bearer based on the second identifier.



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METHODS, ARCHITECTURES, APPARATUSES AND SYSTEMS FOR NETWORK CODING AND DIFFERENTIATED HANDLING IN WIRELESS SYSTEMS PER NETWORK CODING PDU SET

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 63/521,173 filed June 15, 2023, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present disclosure is generally directed to the fields of communications, software and encoding, including, for example, to methods, architectures, apparatuses, systems directed to network coding in wireless systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] A more detailed understanding may be had from the detailed description below, given by way of example in conjunction with drawings appended hereto. Figures in such drawings, like the detailed description, are examples. As such, the Figures (FIGs.) and the detailed description are not to be considered limiting, and other equally effective examples are possible and likely. Furthermore, like reference numerals ("ref.") in the FIGs. indicate like elements, and wherein:

[0004] FIG. 1A is a system diagram illustrating an example communications system;

[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;

[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;

[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;

[0008] FIG. 2 illustrates an example of a codeword defined by the linear combination $C_r = G_r P$;

[0009] FIG. 3 illustrates an example of fixed block coding;

[0010] FIG. 4 illustrates an example of a sliding widow coding;

[0011] FIG. 5 illustrates an example of PDU sets;

[0012] FIG. 6 illustrates an example of a structure of a system overview of network coding;

[0013] FIG. 7 illustrates an example of functional views of a NC Processing functional block;

[0014] FIG. 8 illustrates another example of functional views of a NC Processing functional block;

[0015] FIG. 9 is a diagram illustrating a model for NC operation;

[0016] FIG. 10 illustrates an example of a coherent NC PDU header;

- [0017] FIG. 11 illustrates another example of a coherent NC PDU header;
- [0018] FIG. 12 illustrates an example of non-coherent NC PDU header (NC SDU segmentation-based NC);
- [0019] FIG. 13 illustrates another example of non-coherent NC PDU header (NC SDU segmentation-based NC);
- [0020] FIG. 14 illustrates an example of non-coherent based NC PDU header (NC SDU concatenation based NC);
- [0021] FIG. 15 illustrates another example of non-coherent based NC PDU header (NC SDU concatenation based NC);
- [0022] FIG. 16 is a diagram illustrating an example of NC SDU segmentation based encoding (no NC feedback assumed);
- [0023] FIG. 17 is a diagram illustrating an example of NC SDU segmentation based encoding (NC Feedback assumed);
- [0024] FIG. 18 is a diagram illustrating an example of NC SDU concatenation based encoding (no NC feedback assumed);
- [0025] FIG. 19 is a diagram illustrating an example of NC SDU concatenation based encoding (NC feedback assumed);
- [0026] FIG. 20 is a diagram illustrating an example of NC SDU segmentation based decoding;
- [0027] FIG. 21 is a diagram illustrating an example of NC SDU concatenation based decoding;
- [0028] FIG. 22 is a flowchart illustrating a representative method implemented by a WTRU; and
- [0029] FIG. 23 is a flowchart illustrating a further representative method implemented by a WTRU.

DETAILED DESCRIPTION

[0030] In the following detailed description, numerous specific details are set forth to provide a thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of, or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein. Although various embodiments are described and/or claimed herein in which an apparatus, system, device, etc. and/or any element thereof carries out an operation, process, algorithm, function, etc. and/or any portion thereof, it is to be understood that any embodiments described and/or claimed herein

assume that any apparatus, system, device, etc. and/or any element thereof is configured to carry out any operation, process, algorithm, function, etc. and/or any portion thereof.

[0031] Provided below are acronyms/abbreviations for terms and phrases commonly used in this application:

3GPP	3 rd Generation Partnership Project
5G	5th Generation
AM	Acknowledged Mode
ARQ	Automatic Repeat Request
BSR	Buffer Status Report
BWP	BandWidth Part
CA	Carrier Aggregation
CB	CodeBook
CE	Control Element
CG	Configured Grant
CID	Context ID
CM	Coherent Mode
CSI	Channel State Information
CQI	Channel Quality Information
DC	Dual Connectivity
DCI	Downlink Control Information
DG	Dynamic Grant
DRB	Data Radio Bearer
EHC	Ethernet Header Compression
EV	Encoding Vector
GF	Galois Field
HARQ	Hybrid Automatic Repeat Request
IAB	Integrated Access and Backhaul
ID	Identity or Identifier
L1	Layer-1
L2	Layer-2
L3	Layer-3
LDPC	Low Density Parity Check
LPC	Linear Packet Coding
LTE	Long Term Evolution

MAC	Medium Access Control
MCG	Master Cell Group
MCS	Modulation and Coding Scheme
mTRP	Multi-TRP
NC	Network Coding
NR	New Radio
OC	Outer Coding
OFDM	Orthogonal Frequency Division Multiplexing
PDCP	Packet Data Convergence Protocol
PDU	Protocol Data Unit
PHY	Physical layer
PMI	Precoding Matrix Indicator
PSDB	PDU Set Delay Budget
PSER	PDU Set Error Rate
PSI	PDU Set Importance
PSIHI	PDU Set Integrated Handling Indication
QoE	Quality of Experience
QoS	Quality of Service
RAN or R(AN)	Radio Access Network
RB	Radio Bearer
RLC	Radio Link Control
RI	Rank Indicator
ROHC	Robust Header Compression
RRM	Radio Resource Management
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
RX	Receiver, Receive
SAP	Service Access Point
SCG	Secondary Cell Group
SCI	Sidelink Control Information
SDAP	Service Data Adaptation Protocol
SDU	Service Data Unit
SCS	SubCarrier Spacing
SG	SDUs Grouping

SN	Sequence Number
SPS	Semi-Persistent Scheduling
SRB	Signalling Radio Bearer
TB	Transport Block
TCI	Transmission Configuration Indicator
TRP	Transmission/Reception Point
TX	Transmitter, Transmit
UCI	Uplink Control Information
UDC	Uplink Data Compression
UE	User Equipment
UM	Unacknowledged Mode
UL	Uplink
URLLC	Ultra-Reliable and Low Latency Communications
V2X	Vehicle-to-X Communication
XR	eXtended Reality
XRM	XR Media

[0032] Example Communications System

[0033] The methods, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. An overview of various types of wireless devices and infrastructure is provided with respect to FIGs. 1A-1D, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0034] FIG. 1A is a system 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 (ZT) unique-word (UW) discrete Fourier transform (DFT) spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0035] 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) 104/113, a core network (CN) 106/115, 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" and/or a "STA", may be configured to transmit and/or receive wireless signals and may include (or be) 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.

[0036] 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, e.g., to facilitate access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be any of a base transceiver station (BTS), a Node-B (NB), an eNode-B (eNB), a Home Node-B (HNB), a Home eNode-B (HeNB), a gNode-B (gNB), a NR Node-B (NR NB), 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.

[0037] The base station 114a may be part of the RAN 104/113, 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, etc. 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 an 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 or any sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0038] 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).

[0039] 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 104/113 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 Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0040] 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).

[0041] 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 New Radio (NR).

[0042] 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).

[0043] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (Wi-Fi)), 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.

[0044] 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 an 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 an 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 any of a small cell, 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 106/115.

[0045] The RAN 104/113 may be in communication with the CN 106/115, 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 106/115 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 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing an NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing any of a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or Wi-Fi radio technology.

[0046] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or 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 104/114 or a different RAT.

[0047] 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.

[0048] 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 elements/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.

[0049] 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) circuits, 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, e.g., in an electronic package or chip.

[0050] 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

an 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 an 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.

[0051] 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. For example, the WTRU 102 may employ MIMO technology. Thus, in an 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.

[0052] 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.

[0053] 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).

[0054] 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.

[0055] 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.

[0056] The processor 118 may further be coupled to other elements/peripherals 138, which may include one or more software and/or hardware modules/units that provide additional features, functionality and/or wired or wireless connectivity. For example, the elements/peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (e.g., 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 elements/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, and/or a humidity sensor.

[0057] 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 uplink (e.g., for transmission) and downlink (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 uplink (e.g., for transmission) or the downlink (e.g., for reception)).

[0058] 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, and 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0059] 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 an 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 receive wireless signals from, the WTRU 102a.

[0060] Each of the eNode-Bs 160a, 160b, and 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 uplink (UL) and/or downlink (DL), and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0061] 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 each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the CN operator.

[0062] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, and 160c 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.

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] In representative embodiments, the other network 112 may be a WLAN.

[0068] 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 an access or an interface to a distribution system (DS) or another type of wired/wireless network that carries traffic into 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.

[0069] 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 via signaling. 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.

[0070] 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.

[0071] Very high throughput (VHT) STAs may support 20 MHz, 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 a medium access control (MAC) layer, entity, etc.

[0072] 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).

[0073] 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, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0074] 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.

[0075] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0076] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 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 an 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 WTRUs 102a, 102b, 102c. 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).

[0077] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, 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., including a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0078] 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.

[0079] 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, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards user plane functions (UPFs) 184a, 184b, routing of control plane information towards access and mobility management functions (AMFs) 182a, 182b, and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0080] The CN 115 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 at least one Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0081] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 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 NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b, e.g., 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/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 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 Wi-Fi.

[0082] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 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 UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0083] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, e.g., 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 downlink packets, providing mobility anchoring, and the like.

[0084] The CN 115 may facilitate communications with other networks. For example, the CN 115 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 115 and the PSTN 108. In addition, the CN 115 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 an embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (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.

[0085] 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 any of: WTRUs 102a-d, base stations 114a-b, eNode-Bs 160a-c, MME 162, SGW 164, PGW 166, gNBs 180a-c, AMFs 182a-b, UPFs 184a-b, SMFs 183a-b, DNs 185a-b, and/or any other element(s)/device(s) described herein, may be performed by one or more emulation elements/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.

[0086] 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 may performing testing using over-the-air wireless communications.

[0087] 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.

[0088] Network coding (NC) may be applicable for transmission of coded packets where the system may apply some form of link diversity using one or more transmissions. From the receiver perspective, network coding may determine (e.g., assume) that coded packets may arrive from the same or from a different link. Such diversity may comprise any of the following: frequency diversity such as with carrier aggregation, multi-connectivity (e.g., dual-connectivity), multi-path sidelink or multi-path relaying with at least two paths using different frequency resources; spatial diversity such as with multi-connectivity (e.g., dual-connectivity, multi-TRP, multi-path sidelink); code diversity or a combination thereof.

[0089] The term outer coding (OC) may be applied as a special form of network coding where the transmission of the coded packets may be performed via a single link, for example, with the link diversity being in the form of time domain diversity. From the receiver perspective, this form of network coding may assume that the coded packet arrives from the same link. With NC, coding may be performed at the source as well as at the intermediate forwarding nodes (all or a subset of them). The term end-to-end coding will be used in reference to a special case of a network coding scheme where coding is performed at the source or an equivalent node, and the decoding is performed at the destination or an equivalent node, with no recoding operation at intermediate nodes.

[0090] In this disclosure, unless otherwise specified, the term network coding and outer coding may be used interchangeably. Furthermore, the network coding may refer to any linear block coding techniques (based on finite field arithmetic) that uses a generator matrix to derive codes, and is implemented in a wireless system such as 3GPP-based systems and one or more of its corresponding L1/L2 or L3 protocol layers. Such layer may be L1/PHY, L2/MAC, L2/RLC, L2/PDCP or L3/RRC. When applied at L1/PHY, network coding may provide an additional layer of error resiliency in addition to the error correction or recovery capabilities provided by the existing specified solutions for e.g., channel coding solutions (e.g., LDPC, polar code), HARQ or RLC ARQ error correction mechanisms.

[0091] Some additional definitions are captured below.

[0092] Finite Field: a finite field or Galois Field (GF) is a field that contains a finite number of elements. A field is a set on which addition, subtraction, multiplication, and division are defined and behave as the corresponding operations on rational and real numbers do. As with any field, a finite field is a set on which the operations of multiplication, addition, subtraction and division are defined and satisfy basic rules of arithmetic, with the result of such operation being an element of the said finite field.

[0093] Order or size, characteristics and dimension of a finite field: the order or size of a finite field is its number of elements. The number of elements of a finite field is (e.g., necessarily) of the form u^s where u is a prime number and s is a positive integer. The prime u is called the characteristic of the field, and the positive integer s is called the dimension of the field over its prime field. In this document, a finite field F_q or alternatively denoted $GF(q)$ is a field of size $q = u^s$. Furthermore, in this document, the element of a finite field of size $q = u^s$, will be interchangeably referred to as a symbol of size s .

[0094] Binary Extension Fields: a binary extension field is a finite field F_q with $q = 2^s$. When $u = 2$, the corresponding finite fields are called binary extension fields. Examples of binary extension fields include binary field $GF(2)$ where each element is one bit long, binary-2 field $GF(2^2)$, binary-4 field $GF(2^4)$ field, and binary-8 field $GF(2^8)$ where each element is one byte long. In enumeration form, $GF(2)$ is the set $\{0,1\}$, $GF(2^2)$, is the set $\{00,01,10,11\}$, $GF(2^4)$ is the set $\{0000,0001,0010,0011, 0100,0101,0110, 0111, 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111\}$, etc. Since a packet size is usually larger than the field size, each packet is seen as a set of elements from the Galois field (usually referred to as symbols) appended together. Without loss of generality, it may be assumed that the packets have a fixed number of symbols (Galois field elements), and since all the operations are performed over Galois fields, then the size of the packets does not change with subsequent linear combinations.

[0095] Fixed rate code: A coding scheme where the coding rate is fixed before transmission. The codeword is either successfully decoded at the receiver or unsuccessfully decoded. No additional redundancy bit is transmitted. Under a fixed code rate scheme, for a given generation of input packets, there is (e.g., only) one iteration of network coding, leading to a transmission of a fixed number of coded packets (a fixed size codeword), where the fixed number of coded packets is dictated by the selected fixed code rate.

[0096] Rateless codes: rateless code are codes used for encoding data to generate incremental redundancy codes and then, are transmitted with variable packet error rate. The interpretation of the terminology rateless is that the codes do not fix its code rate before transmission. Rather, it can (e.g., only) be determined after correctly recovering the transmitted data. In the literature, the rateless code is typically referred to by some associated terminologies such as "variable-rate," "rate-compatible," "adaptive-rate," or "incremental redundancy" scheme. However, the rate of a rateless code can be considered in two perspectives e.g., as the instantaneous rate and the effective rate. The instantaneous rate is the ratio of the number of information bits to the total number of bits transmitted at a specific instant. On the other hand, the effective rate is the rate realized at the specific point when the codeword has been successfully received. Considering a codeword $C_r = G_r P$, where G_r is the generator matrix with k columns and r rows as defined earlier, the code rate is k/r . With rateless coding, additional rows can be added to the generator matrix G_r , or equivalently additional coded packets can be added to the codeword C_r , thereby increasing the amount of redundancy and decreasing the code rate. For rateless coding scheme, for a given generation of input packets, there is one or more network coding iterations. An initial codeword (initial set of coded packets) targeting an initial code rate is generated in a first iteration of network coding. This codeword is updated, with additional coded packets generated and transmitted at one or more (e.g., each) subsequent iterations of network coding until the input packets are successfully decoded by the receiver, or the decoding is eventually declared to have failed (for e.g., after a predefined maximum number of iterations of the minimal expected code rate is achieved or surpassed). In this disclosure, the term code rate without any qualifier, will be used in reference to the instantaneous code rate, e.g., the code rate at a given iteration of network coding.

[0097] Original payload, packet, or symbol, uncoded payload, packet or symbol, systematic payload, packet, or symbol, source payload, packet or symbol: a unit of data originating from the source that is used as input to encoding operations. In this disclosure, this unit of data will be referred to as a NC SDU (Service data Unit) or NC SDU segment (for the case where the NC perform segmentation of input packet). It should be noted, that as defined earlier, the operations

of multiplication (or division) and addition (or subtraction) for encoding and decoding operations are performed symbol-wise.

[0098] Coded payload, packet or symbol, repair payload, packet or symbol: a unit of data that is the result of a coding operation, applied either to source symbols or (in case of recoding) source and/or repair symbols. In this disclosure, this unit of data will be denoted NC PDU payload, e.g., NC PDU without NC header.

[0099] Input Symbol and Output Symbol: a unit of data that is used as input to an encoding operation or that is generated as output of an encoding operation. At a recoding node, repair symbols are also part of the input symbols. With systematic coding, source symbols are also part of the output symbols, Same definition applies in terms of payload or packet. In this disclosure, this unit of data used as input to the encoding operation will be referred to as a NC SDU (Service data Unit). This unit of data could also be referred to pre-NC PDU or Pre-NC PDU payload if the NC upper layer protocol header is not included in NC encoding. In this disclosure, NC SDU, pre-NC PDU or pre-NC PDU payload will be used interchangeably unless otherwise specified. The unit of data that is generated as output of encoding operation will be referred to as a NC PDU payload.

[0100] Encoding symbol: a source symbol, or in case of recoding a coded symbol or a repair symbol. Same definition applies in terms of payload or packet.

[0101] (En)coding versus recoding versus decoding: (en)coding is an operation that takes source symbols as input and produces coded symbols as output. Recoding is an operation that takes coded symbols as input and produces coded symbols as output. Decoding is an operation that takes coded symbols as input and produces source symbols as output. Same definition applies in terms of payload or packet.

[0102] Systematic coding: a coding technique where source symbols are part of the output coded symbols e.g., output from the encoding operation.

[0103] Transparent mode: a scheme where network coding is not part of the TX or RX processing.

[0104] Coherent network coding: a network coding scheme where one or more of the generator matrix, the topology of the network between the source and destination, is assumed known to the destination (e.g., the end-receiver). Note: Since the broader framework may involves recoding at intermediary nodes between the source and end-destination, a coherent network coding might not always be possible, since the route of the packets, the recoding instances along the way, and therefore the final coding coefficients applicable at the end-destination might not be known ahead of time.

[0105] Non-coherent network coding: a network coding scheme where none of the one or more of the generator matrix, the topology of the network between the source and destination, is known to the destination (e.g., the end-receiver).

[0106] Codebook based network coding: a network work coding scheme where a codebook, or one or more of the codewords is assumed known to the destination (e.g., the end-receiver).

[0107] Non-codebook based network coding: a network work coding scheme where no codebook, or no codeword is assumed known to the destination (e.g., the end-receiver).

[0108] Adaptive network coding: network coding scheme that enables dynamic control, and adaptation of network coding operation over lossy channels by e.g., configuring and adapting coding parameters (e.g. generation, generation size, transmission of output/coded packets) to meet the instantaneous delay-throughput-reliability requirements according to the radio condition changes (the channel variation) over time, accounting for the possibly loss of degree of freedom due to erasures (i.e. packet drops) or transmission errors (i.e. bit errors during transmission). In this disclosure, a feedback-based network coding scheme is one form of adaptive network coding where the transmitter adapts network coding operation based on feedback (e.g., successful decoding or failed decoding) the from (peer or remote).

[0109] NC SDU segmentation-based NC: a network coding scheme where NC SDUs may be segmented into NC SDU segments, and packet generations may comprise of (e.g., only) NC SDU segments. Re-assembly of NC SDU segments is performed at the end destination (decoder) to form the original NC SDU.

[0110] NC SDU concatenation-based NC: a network coding scheme where packet generations comprise of (e.g., only) NC SDUs.

[0111] Hybrid NC SDU segmentation or concatenation-based NC: a network coding scheme where packet a generation comprises of NC SDUs or NC SDU segments. This scheme will be denoted hybrid segmentation or concatenation based NC.

[0112] Linear Network Coding (over a finite field): in linear network coding, the packet alphabet A is a q -element finite field F_q , or more generally, a space of row vectors over F_q . In a packetized communication network, one or more (e.g., each) packet p can be represented by an m -dimensional (row) vector over a finite field F_q , e.g., a vector of m elements or symbols from the finite field F_q . In other words, the bits in one or more (e.g., each) packet are grouped into symbols of size s bits from F_q , $q = 2^s$. We thus consider each packet as a vector of m symbols from F_q , each symbol being of size s . We will refer to such a vector as a packet vector. In this document, the term packet and packet vector will be used interchangeably. Due to the algebraic nature of this construction, it is possible to perform algebraic operations among different packets (e.g., vectors) to obtain a new

packet in the vector space. Such ability yields the (linear) network coding capability of the network. (Linear) network combination refers to the mode of transmission of any network node where any linear combination of a set $\{p_i\}_{1 \leq i \leq k}$, of available packets can be formed. Specifically, we have

$$c = \sum_{i=1}^k g_i p_i \quad (1)$$

where $g_i \in F_q$, for each i constitute the coding coefficients, and k represents the number of packets being linearly combined to form a coded packet. It should be noted that the coding coefficients g_i may be randomly selected, in which case the network coding scheme is referred to random linear network coding. Assuming a time-slotted system operation, the linear combination of a set of available packets in time slot t , can be formed as:

$$c[t] = \sum_{i=1}^k g_i[t] p_i \quad (2)$$

For sake of simplicity, we will ignore the reference to the time instance of a linear combination of packets and will describe a linear combination of a packets as per the equation (1) above.

[0113] Expanding on the above, let $p_1, \dots, p_k$ denote the packet vectors to be encoded, which are length- m row vectors of symbols from F_q . We denote by P the $k * m$ matrix whose i th row is p_i . Let C_r be the matrix whose rows are given by the r 's coded packet vectors. P and C_r are linearly related by a matrix equation $C_r = G_r P$.

[0114] The matrix G_r is the matrix of the coding coefficients, with k columns and r rows, where each coding coefficient is an element of the finite field F_q . This matrix will be called herein, the generator matrix, generation matrix, or the transfer matrix.

[0115] It should be noted that the row space of C_r is a subspace of the row space of P . If the receiver receives k linearly independent packets, it can recover the row space of P , e.g., the receiver can recover the encoded packet $p_1, \dots, p_k$, if it received k linearly independent coded packets out of r coded packets. Let $C(F_q^m)$ denote the set of all subspaces of F_q^m . A codeword corresponds to a nonempty subset of $C(F_q^m)$, and each codeword is a subspace of F_q^m . In other words, a codeword is any subset of coded packets that can be generated as a linear combination of packet $p_1, \dots, p_k$. A codeword is transmitted as a batch of k packets; the k packet vectors representing the packets being encoded together in the batch form a generating set for the corresponding subspace (or its orthogonal complement). The terms generating set, input packets generation, generation of input packets or simply generation will be used interchangeably in this disclosure. The term "set of packets being coded together" or "set of packets being encoded

together" should be understood as the set of packets used as input to the (en)coding operation, independently of the fact that these source packets have been selected for linear combinations. It is natural to consider codes whose codewords all have the same dimension k . Therefore, codewords of particular interest are any matrix C_r of coded packets, with r number of rows such as $r \geq k$. For a binary field extension, a codeword may be defined by the parameters m , s , k and r , where m is the length expressed in number of symbols of row vectors (i.e. coded packets) in the codeword, s is the symbol size, k is the generation size i.e. the number of packet being coded together, r is the number of rows in the generator matrix i.e. the number of coded packet vectors. In the case of binary extension field with characteristic $u = 2$, it should be noted that if a packet is of size L bits, $L = m * s$ bits, where s is the size of a symbol in the finite field F_{2^s} .

[0116] Let's M denotes the maximum length of a packet vector e.g., the maximum number of symbols in a packet. A codebook is defined herein as all possible codewords from $C(F_q^M)$. A codebook may also be associated with a maximum R number of rows. Let denote G_R , the generator matrix associated with the largest possible codeword C_R , by the equation $C_R = G_R P$. The generator matrix G_R comprises K columns and R rows where, K is an upper bound to the maximum generation size (the maximum number of packets to be encoded together) and R is an upper bound to the maximum number of rows (the maximum number of coded packets that can be generated). An example of a codeword defined by the linear combination $C_r = G_r P$ is illustrated in FIG. 2. Each element in the matrixes C_r , G_r , and P , is an element e.g., symbol from the finite field F_q . In the case of a binary extension field F_{2^s} , each symbol is s bits long. It should be noted that since each packet (or interchangeably packet vector is just an appended set of Galois field elements or symbols, the operations of multiplication (or division) and addition (or subtraction) are performed symbol-wise over each of the individual symbols of the packets. The size of an encoding vector associated with a coded packet c_l is $k * s$ (read as k times s) bits where k is the generator size and s is the symbol size in bits. The matrix P of packets to be encoded is characterized by the parameter m , s and k , where m is the length expressed in number of symbols of row vectors (e.g., coded packets) in the codeword, s is the symbol size, k is the generation size e.g., the number of packets being coded together.

[0117] The set of packets $\{p_i\}_{1 \leq i \leq k}$ being considered for a linear combination to form a coded packet $\{c_i\}_{1 \leq i \leq k}$, e.g., the set of source packets used an input to the encoding operation may be denoted a packet block or an (en)coding window. The block size k is the number of packets in the set of packets being coded together e.g., the size of the (en)coding window. The size may change over time. The block size is equal to the size of the generator matrix G . In a fixed block coding, the block size k is fixed. In a variable block coding, the block size k is rather variable e.g., dynamic.

In this disclosure, a non-sliding window coding is defined as a fixed block coding where the encoding and decoding is on a per-block basis e.g., on a fixed set of packets, see FIG. 3.

[0118] A sliding window coding can also be performed, where the coding is performed across a dynamic set of packets $\{p_i\}_{1 \leq i \leq k}$, see FIG. 4. Packets to be encoded (e.g., source or native packets) can be added or removed from the sliding window dynamically. The sliding window can be of a fixed block size or of a variable block size e.g., a sliding window coding can be performed based on a variable block size or a fixed block size.

[0119] The decoding window is similar to the (en)coding window but from the perspective of the receiver, e.g., the set of source packets that are considered in the current linear system of a receiver, independently of the fact that these source packets have been received, decoded or lost. The size of the decoding window is the number of source packets in the current decoding window. The size may change over time.

[0120] 3GPP QoS/QoE and Packet Data Units (PDU) sets

[0121] There may be dependencies between data transmitted as separate packets. The system may create an association between different packets to enable differentiated handling of packets and/or groups of inter-dependent packets. Such association may be within packets of a same packet flow, or possibly across packets of different flows. Such association may be a configuration aspect of the UE. A flow may be further associated to a specific radio access bearer e.g., a data radio bearer or similar. Differentiated handling may include providing upper bounds in terms of latency, jitter, packet loss rate, residual bit errors or other QoS/QoE-related metrics for a given PDU set.

[0122] For both uplink and downlink operation, data may be represented in terms of PDU set and data burst. A data burst may be a set of data PDUs generated and sent by an application in a short period of time. A PDU set may be composed of one or more PDUs carrying data where data in different PDUs has some dependency with data from other PDUs in the same set. For example, a PDU set may carry the payload of one unit of information generated at the application level (e.g., a frame or video slice for XR Media (XRM) Services). For example, a PDU set may carry the video payload of an augmented reality virtual element, its kinaesthetics (e.g., movement) information and related haptics data. Hereafter, PDU sets may be described in terms of the same QoS flow without restricting a definition based on other association between packets of different flows.

[0123] In some implementations, one or more (e.g., all) PDUs in a PDU set are needed by the application layer to use the corresponding unit of information. In other implementations, the application layer can still recover parts all or of the information unit, when some PDUs are missing. FIG. 5 provides an illustration of PDU sets.

[0124] A data burst may be composed of multiple PDUs belonging to one or multiple PDU sets. During a data burst, periods of data transmission inactivity may not be assumed. Although the duration of data bursts can vary, it may be assumed that it stays within the same order of magnitude.

[0125] The following PDU set related information may be visible to both the WTRU (e.g., UE) and RAN access stratum: (1) PDU set QoS parameters of the QoS flow; (2) PDU set information; (3) PDU set Importance (PSI); (4) end of data burst indication; and (5) dependent PDU set's sequence number.

[0126] PDU set QoS parameters of the QoS flow (e.g., applicable to one or more (e.g., all) PDU sets of the QoS flow). PDU set QoS parameters may comprise any of the following parameters: (i) PDU set error rate (PSER): defines an upper bound for the rate of PDU sets that have been processed by the sender of a link layer protocol but that are not successfully delivered by the corresponding receiver to the upper layer; (ii) PDU set delay budget (PSDB): time between reception of the first PDU and the successful delivery of the last arrived PDU of a PDU set. PSDB is an optional parameter; (iii) PDU set integrated handling indication (PSIHI) e.g., whether one or more (e.g., all) PDUs are needed for the usage of PDU set by application layer.

[0127] PDU set information, it may comprise any of the following parameters: (i) PDU set sequence number; (ii) PDU set size in bytes; (iii) PDU SN within a PDU set; and (iv) end PDU of the PDU set.

[0128] PDU Set Importance (PSI): this parameter may be used to identify the importance of a PDU set within a QoS flow. RAN may use it for PDU set level packet discarding in presence of congestion.

[0129] End of data burst indication may be in the header of the last PDU of the data burst (optional).

[0130] Dependent PDU set's sequence number maybe known. For example, if the current PDU set 2 is dependent on PDU set 1, the PDU set 2 should carry the PDU set 1's sequence number.

[0131] For the uplink traffic, the WTRU (e.g., UE) may identify PDU set and data bursts dynamically but in-band marking over Uu of PDUs is not needed. When the PSIHI is set for a PDU set, as soon as one PDU is known to be lost, the remaining PDUs of that PDU set may be considered as no longer needed by the application and may be subject to discard operation.

[0132] Example of use cases and deployments for Network Coding

[0133] NC may be applied to further improve reliability and/or reduce latency of wireless transmissions in a number of connectivity scenarios and data services. For example, it may improve data transmissions for real-time immersive and multi-sensory communication and services, such as XR or Metaverse, as well as providing communication services required for

connected industries and automation that may have latency requirements as low as in the sub-10ms or even sub.ms ranges.

[0134] The 5G NR design support PDCP duplications and other plain duplication redundancy techniques in support of ultra-reliable and low latency communication services. Considering increasing requirements in terms of various key performance metrics such as spectral efficiency, latency, reliability, data rate and the need for a concurrent support of these requirements, the use of redundancy via plain duplication as a solution is not efficient and not scalable.

[0135] Network coding can provide flexible redundancy coding rate for different reliability requirements and flexible split of transmission of coded packets over different transmission paths (e.g., frequency diversity, spatial diversity, code diversity) or over different time instances (for time domain diversity).

[0136] In reference to the existing 5G system, network coding can be used to improve efficiency for the support of multicast broadcast services, sidelink services (e.g., V2X services), enhanced mobile broadband services with the added benefits of better link efficiency, reduced latency, improved reliability and reduced buffering requirements. Example of deployment scenarios includes CA (Carrier Aggregation), DC (Dual Connectivity), IAB (Integrated access and backhaul), sidelink including sidelink relay.

[0137] A problem addressed herein is how to introduce and enable network coding in various protocols layers of wireless systems. The focus is on handling PDUs as output of the network coding process in terms of differentiated processing based on the properties of the network-coded PDUs when applied over the cellular (Uu) interface or the Sidelink/PC5 interface.

[0138] Possible benefits of network coding including improving reliability under tight latency requirements. Network coding may be applied with or without duplication, or with traditional packet repetition; use of network coding may alleviate a scheduler from having to select conservative MCS transmission parameters and/or improve the allocation of other transmission resources to improve overall system performance.

[0139] Network coding, or PDU differentiation based on network coding, is not supported in 3GPP radio protocols. Methods to extend radio interface architecture/protocols and procedures with minimum protocol overhead in support of network coding may include methods to adapt processing of network coded PDUs and enhancements to existing transmitter and receiver processing.

[0140] Differentiated handling per NC PDU SET

[0141] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may assign sequencing,

identification information for one or more (e.g., each) PDU of the NC PDU set and/or within the header of the resulting MAC PDU. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing.

[0142] The WTRU (e.g., UE) may apply differentiated handling of PDUs that have been processed by NC coding per PDU or per set of PDUs using one or more criteria, e.g., PDU size, semi-static configuration, dynamic signaling and/or UE-autonomous determination.

[0143] Differentiated handling, physical processing

[0144] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., either a) spread PDUs of a same NC PDU set over different, possibly determined by configuration, diversity path based on a differentiation for one or more parameters (e.g., related to time, space, frequency or code) or restrict one or more (e.g., all) of PDUs to a single diversity path or b) perform such determination based on explicitly received signaling, which signaling may possibly override other UE-autonomous determination of how to apply mapping of a PDU to a diversity path.

[0145] The WTRU (e.g., UE) may be configured to apply differentiated handling of one or more PDUs processing with network coding (e.g., Linear Packet Coding). The WTRU (e.g., UE) may apply differentiated handling of one or more PDUs processing with network coding at the physical layer, e.g., by selecting specific L1 resources (time, space, frequency) and/or transmission methods (waveform, MIMO/beamforming technique, scheduling method, etc.).

[0146] Differentiated handling, Layer 2 processing

[0147] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., a) either spread PDUs of a same NC PDU set over different, possibly determined by configuration, LCHs or restrict one or more (e.g., all) of PDUs to a single LCH, b) either spread PDUs of a same NC PDU set over different, possibly determined by configuration of such multiplexing priority, TBs or give highest priority to one or more (e.g., all) of PDU to the same TB.

[0148] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., map PDUs of a same NC PDU set over specific transmission resources as determined from a property of the scheduling information and/or the transmission parameters.

[0149] The WTRU (e.g., UE) may be configured to apply differentiated handling of one or more PDUs processed with network coding (e.g., LPC) at L2 processing e.g., by selecting specific L2 bearers, L2 instance (e.g., PDCP, RLC and/or MAC instance(s)), LCH, MAC multiplexing or processing/diversity path (possibly including enabling duplication).

[0150] "Differentiated handling of NC PDUs" can be defined as comprising (e.g., consisting) of processing differently, different NC PDUs or group of NC PDUs with different processing methods, or resources in one or more protocol layers e.g., L1 layer, L2 layer, L3 layer, etc. Such processing methods or resources are denoted herein for simplicity NC PDU bearers. An NC PDU bearer may include one or more NC PDU L1 bearer, NC PDU L2 bearer, or NC PDU L3 bearer. Additionally, an NC PDU bearer may further include NC PDU L4 (transport layer) bearer for e.g., if NC function is implemented in the transport layer or above. The processing methods may include transmission methods or receptions methods". One or more (e.g., each) NC PDU bearer is characterized by a setup or configuration in one or more protocol layers e.g., L1 layer, L2 layer, L3 layer. A WTRU (e.g., UE) may treat two NC PDU bearers as different bearers if the two NC PDU bearers differ by at least one of their attributes/characteristics e.g., configuration (or setup) parameters. The sequence of PDUs created as a consequence of NC processing may be treated for transmission as part of the normal radio bearer treatment, or using new methods for differentiated handling derived from the specific characteristics of the network-coded PDUs. Differentiated handling may include subsequent L3/L2/L1 processing including mapping to specific transmission methods and resources.

[0151] Expressed differently: another way to conceptualize "NC PDU bearer" is "differentiated processing/handling/treatment for Linear Packet Coding (LPC)-processed PDUs based on characteristics of such PDUs".

[0152] In this disclosure, a diversity path can be conceptualized or defined as an NC PDU bearer, among a plurality of NC PDU bearers associated with one or more NC PDUs, where one or more NC PDU bearers among the plurality of NC PDU bearers are considered diversity bearers for the purpose of handling/treating differently or providing redundant processing to the one or more said NC PDUs. One realization of a diversity bearer or diversity path is a scenario where among the plurality of diversity bearer associated with one or more NC PDUs, one or more NC PDU bearers of the said plurality of NC PDU bearers may be designated or setup/configured as primary NC PDU bearer(s), and one or more NC PDU bearers of the said plurality of NC PDU bearers may be designated or setup/configured as secondary NC PDU bearer(s).

[0153] NC Processing Control

[0154] The WTRU (e.g., UE) may be configured e.g., by L3/RRC signaling to apply network coding. The configuration may include parameters for differentiated handling of the NC processing PDUs.

[0155] The NC Control controls the NC Processing features and behaviors by means of one or more inputs into NC Processing. The WTRU (e.g., UE) may receive configuration or other control information from the base station (or peer WTRU (e.g., UE) or remote WTRU (e.g., UE) e.g., in case of NC applied over a sidelink/PC5 air interface) by mean of control signaling (in control plane or user plane) between the NC Control entity in the WTRU (e.g., UE) and the peer Control entity in the base station (or peer WTRU (e.g., UE) or remote UE). The control of the NC Processing by NC Control may be semi-static, or dynamic, or both.

[0156] The control (NC control granularity) may be per NC PDU bearer (as defined in this disclosure), per-QoS flow basis, per-bearer basis (e.g., DRB, SRB), per-traffic flow basis, per NC SDU or SDU segment basis, per NC SDU set or pre-NC PDU set basis, per-output packet (NC-PDU) basis, per NC PDU set basis, or a combination thereof. The one or more inputs used by the NC Control to control NC Processing may be semi-static, dynamic. Some of the inputs might be configurable (for e.g., by the base station) semi-statically or dynamically (explicit control).

[0157] In another embodiment, the local NC Control at the transmitting WTRU (e.g., UE) (for e.g., in the UE) may dynamically controls the NC processing (implicit control), taking into account any of:

- a) channel quality or variation in channel quality at the receiver (for e.g., at the peer node or remote node) identified through measurements made at the transmitter and/or reported by the receiver;
- b) buffer status;
- c) configuration e.g., received from the base station (e.g., QoS/QoE-related metrics, pre-NC PDU set specific QoS parameters of the QoS flow, pre-NC PDU size, pre-NC PDU set size, relative importance of pre-NC PDU within a pre-NC PDU set, pre-NC PDU set integrated handling indication (PSIHI), relative importance of pre-NC PDU set within a set of pre-NC PDU sets;
- d) scheduler information (e.g., resource grant amount, resource grant type e.g., CG grant, SPS grant, dynamic grant, transport block size decided by the scheduler, modulation and coding scheme, redundancy version, power headroom, Tx power level; and
- e) feedback received e.g. from the RX NC processing.

[0158] In addition to the NC control granularity (e.g., per bearer) described above, the inputs into NC Processing may also be separately defined on the basis of device capability, which set bounds

around possible values for the NC control granularity described above. For example, one or more (e.g., each) configuration described in this document, in addition to be defined and configured into the WTRU (e.g., UE) on the basis of NC control granularity defined above, may also be subject to minimum value(s), maximum value(s), default value(s) separately defined and configured into the WTRU (e.g., UE) on the basis of device capability. To enable this, the WTRU (e.g., UE) communicates its NC device capabilities to the base station (or peer WTRU (e.g., UE) or remote UE).

[0159] Input to NC Processing

[0160] The NC Control controls NC processing by means of one or more of the following configurable and/or controllable parameters (NC Processing input), the WTRU (e.g., UE) may receive from the base station, or a peer WTRU (e.g., UE) or remote WTRU (e.g., UE) or a combination thereof. One or more (e.g., each) of these inputs may be configured as a list e.g., one or more, for example on the basis of any of the control granularity (e.g., per-bearer) defined in this disclosure.

[0161] Galois field & linear system related input: (1) symbol/coding coefficient (s) size (as defined in previous sections, or as described herein in other sections): positive integer value, expressed in number of bits (octet); (2) maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); (3) default, initial, or target value

[0162] Galois Field size related input: (parameter q as defined in previous sections or as described herein in other sections): positive integer value, $q = 2^s$ (s in bits); maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial or target value.

[0163] Generation size related input: (number of input packets into coding operation or parameter k as defined in previous sections or as described herein in other sections): positive integer value, expressed in number of input packets. May also be expressed in numbers of symbols, bits, octets, etc.

[0164] Generation type related input: fixed block coding, sliding window coding.

[0165] The following generation type and generation size configuration related parameters (e.g., List of level 2 configurable and/or controllable parameters) may be defined for fixed block coding, or sliding window coding.

[0166] Fixed block coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to window size Maximum value/minimum value; the

maximum and minimum values may be configured for example in support of variable fixed block coding in support of dynamic control of NC Processing at the WTRU (e.g., UE), or for example to control when NC PDUs should be generated.

[0167] Fixed block coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to window size default, initial or target value.

[0168] Fixed block coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to Pre-NC PDU set based; the WTRU (e.g., UE) may determine dynamically, the generation size as a function of the number of packets in one or more pre-NC PDU sets whose packet are included into input packet generation for this NC context.

[0169] Fixed block coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to time-based: number of input packets (e.g., NC SDUs or NC SDU segments) available at a given time instant.

[0170] Fixed block coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to time-window based: input packets (e.g., NC SDUs or NC SDU segments) available during a given time window.

[0171] Sliding window coding (as defined in previous sections or as described herein in other sections) may comprise parameters related window size Maximum value/minimum value; the maximum and minimum values may be configured for example in support of variable sliding window coding in support of dynamic control, or for example to control when NC PDUs should be generated.

[0172] Sliding window coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to window size Default, initial or target value.

[0173] Sliding window coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to sliding step value (how many input packets is jointly added or removed from the window at a time once the sliding window is initialized with a number of input packets) – Maximum value/minimum value. The sliding step can be defined and configured in terms of two separate parameters, for e.g., sliding step for input packet addition to the sliding window (referred to here as packet addition sliding step) and sliding step for input packet removal from the sliding window (referred to here as packet removal sliding step). The parameters may comprise any of: (1) maximum value /minimum value for sliding step or, (2) maximum value /minimum value for packet addition sliding step and, (3) maximum value /minimum value for packet removal sliding step. Sliding step default, initial or target value. Default value can be set to 1. Packet addition sliding step default, initial or target value. Default value can

be set to 1. Packet removal sliding step default, initial or target value. Default value can be set to 1.

[0174] Sliding window coding (as defined in previous sections or as described herein in other sections) may comprise parameters related to time-based window sliding for e.g., sliding window is slide by a sliding step after a time period/duration.

[0175] The following list of configurable and/or controllable parameters e.g., shaping input and output characteristics may be defined.

[0176] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the length of Input packet/Output packet (as defined in previous sections or as described herein in other sections): positive integer m (as defined in previous sections or as described herein in other sections), expressed in number of symbols may also be expressed in number of bits, or octets, etc. The parameters may comprise any of maximum value/minimum value, default, initial or target value.

[0177] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the generator matrix (as defined in previous sections or as described herein in other sections).

[0178] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the number of columns $\tilde{K}$: positive integer value, bounded by $\hat{K}$, the maximum possible value of number of columns in a look-up generator matrix. The parameters may comprise any of maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial or target value.

[0179] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the number of rows $\tilde{R}$: positive integer value, bounded by $\hat{R}$, the maximum possible value of number of rows in a look-up generator matrix. The parameters may comprise any of maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial or target value.

[0180] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the symbol size (s) size (as defined in previous sections or as described herein in other sections).

[0181] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the generator matrix ID: positive integer value; WTRU (e.g., UE) may be configured with one or more generator matrices.

[0182] The list of configurable and/or controllable parameters e.g., shaping input and output characteristics may comprise parameters related to the generator matrix elements (coding coefficient/symbols values from the corresponding GF):

[0183] Generator matrix elements may be randomly generated and may comprise any of: (1) symbol size (s) size (as defined in previous sections or as described herein in other sections); (2) random generation seed value; (3) matrix elements (coding coefficient values) generated per row e.g., per coded packet (e.g., from lowest index column to highest index column, or from highest index column to lowest index column); (4) matrix elements (coding coefficient values) generated per column (e.g., from lowest index row to highest index column, or from highest index row to lowest index row).

[0184] Generator matrix elements may be deterministically generated. For example, using a look-up/(pre)configured generator matrix approached.

[0185] Generator matrix elements may comprise consecutive rows and columns based approach: starting column index, starting row index, end column index, end row index. Note: one or more (e.g., each) index points to specific row or column in a generator matrix (pre)configured into the WTRU (e.g., UE); index/identifier of the (pre)configured generator matrix.

[0186] Generator matrix elements may comprise non-consecutive rows, or columns based approach: list of indexes of columns, list of indexes of rows. One or more (e.g., each) index points to specific row or column in a look-up generator matrix; index/identifier of the (pre)configured generator matrix.

[0187] Generator matrix elements may comprise Identifier/Index to a generator matrix known to the WTRU (e.g., UE) for e.g. (pre)configured into the WTRU (e.g., UE).

[0188] Generator matrix elements may comprise index to a sub-generator matrix within a generator matrix known to the WTRU (e.g., UE) for e.g. (pre)configured into the WTRU (e.g., UE). In this approach, a generator matrix may be composed of several sub-generator matrices, where a sub-generator matrix is made of a subset of rows and subset of columns within the set of rows and columns respectively, of a generator matrix. Identifier/Index of the generator matrix known to the WTRU (e.g., UE) for e.g. (pre)configured into the WTRU (e.g., UE).

[0189] Generator matrix elements may comprise elements (coding coefficients/symbols) of the matrix, drawn from the corresponding GF (with symbol size (s) size as defined in previous sections or as described herein in other sections) are explicitly (pre)configured into the WTRU (e.g., UE)

[0190] Generator matrix may include a systematic code generator matrix.

[0191] A subset of the rows of the generator matrix may be generated in support of systematic packets e.g., the corresponding coded packets are same as the input packets. In this case, one or

more (e.g., all the) bits of the coding coefficient of the packet to be transmitted as systematic packet is set to 1, while the bits of the coding coefficients of one or more (e.g., all) other packets in the packet generation (packets of the encoding window) are set to 0. The coefficient remaining of the rows of the generator matrix.

[0192] The remaining coefficients of the generator matrix (remaining rows) may be generated using one or more of the random generation methods or deterministic generation methods described above.

[0193] As specified in this disclosure, the WTRU (e.g., UE) may control the use of systematic code, on the basis on any of the control granularity level defined in this disclosure. For example, some RLC legs/bearers or logical channel bearers may be configured to support (e.g., only) systematic packets while some other RLC leg bearers or logical channel bearers of the same radio bearer (e.g., DRB or SRB) may be configured to support non-systematic coded packets, for example combination of systematic and non-systematic coded packets. When an RLC bearer or logical channel bearer is configured to support (e.g., only) systematic coded packet, the transmitting WTRU (e.g., UE) may use an NC PDU header type that doesn't include coding coefficient, when explicit coding coefficient in NC PDU header-based approach is used for NC encoding vector signaling.

[0194] The following list of configurable and/or controllable parameters e.g., shaping operation/performance characteristics may be defined for coding rates: fixed code rate; and rateless code rates.

[0195] Fixed code rate (as defined in previous sections or as described herein in other sections) may comprise any of: maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial, or target value. Options for configuration include any of: (1) configured as ratio k/r , as defined in previous sections or as described herein in other sections, where the parameters k and r denote the number of columns and the number rows of the generator matrix for the corresponding iteration of network coding; (2) number of additional redundant of packets to be transmitted: positive integer. Note: The total number of coded packets e.g., output packets, is the sum of the input packets and this number of additional redundant packets; (3) redundancy version or code rate index: positive integer. In this option, a list, a sequence, or enumeration of code rates may be specified or (pre)configured into the WTRU (e.g., UE). The redundancy version of the code rate index points to code rate at the position in the list, set, of enumeration.

[0196] Rateless code rates (as defined in previous sections or as described herein in other sections) may comprise any of: (1) sequence of code rates; (2) sequence of redundancy versions or code rate indexes; and (3) maximum number of iterations of NC operation.

[0197] Sequence of code rates may comprise any of maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial, or target value.

[0198] Options for configuration include any of:

[0199] (1) configured as ratio k/r as defined in previous sections or as described herein in other sections, where the parameters k and r denote the number of columns and the number rows of the generator matrix for the corresponding iteration of network coding.

[0200] (2) number of additional redundant of packets to be transmitted for the corresponding interaction of NC coding: positive integer. Note: The total number of coded packets e.g., output packets, is the sum of the input packets and this number of additional redundant packets.

[0201] (3) redundancy version or code rate index for the corresponding iteration of NC coding: positive integer. In this option, a list, a sequence, or enumeration of code rates may be specified or (pre)configured into the WTRU (e.g., UE). The redundancy version of the code rate index points to code rate at the position in the list, set, of enumeration.

[0202] Sequence of redundancy versions or code rate indexes may be defined as: positive integer. In this option, a list, a sequence, or enumeration of code rates may be specified or (pre)configured into the WTRU (e.g., UE). The redundancy version of the code rate index points to code rate at the position in the list, set, of enumeration.

[0203] Maximum number of iterations of NC operation may comprise any of maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial, target value, or fixed value.

[0204] The following list of configurable and/or controllable parameters e.g., for codebook-based operation may be defined with any of: (1) number of columns in a codebook $\tilde{M}$; (2) number of rows $\bar{R}$; (3) symbol size (s) size; (4) codebook ID; (5) codebook elements.

[0205] Number of columns in a codebook $\tilde{M}$ may be defined as: positive integer value, bounded by $\hat{M}$, the maximum possible value of number of columns in a look-up codebook.

[0206] Number of rows $\bar{R}$ may be defined as: positive integer value, bounded by $\bar{\bar{R}}$, the maximum possible value of number of rows in a look-up codebook.

[0207] Symbol size (s) size may be defined as in previous sections or as described herein in other sections.

[0208] Codebook ID may be defined as: positive integer value; WTRU (e.g., UE) may be configured with one or more codebooks.

[0209] Codebook elements (coding coefficient/symbols values from the corresponding GF) may be randomly generated. It may comprise any of the following parameters: (i) symbol size (s) size (as defined in previous sections or as described herein in other sections); (ii) random generation seed value; (iii) codebook elements (coding coefficient values) generated per row e.g., per coded packet (e.g., from lowest index column to highest index column, or from highest index column to lowest index column); (iv) codebook elements (coding coefficient values) generated per column (e.g., from lowest index row to highest index column, or from highest index row to lowest index row)

[0210] Codebook elements (coding coefficient/symbols values from the corresponding GF) may be deterministically generated. For example, using a look-up/(pre)configured codebook approached.

[0211] For example, using consecutive rows and columns based approach, codebook elements may comprise any of the following parameters: starting column index, starting row index, end column index, end row index. Note: one or more (e.g., each) index points to specific row or column in a codebook (pre)configured into the WTRU (e.g., UE). Codebook elements may comprise any of the following parameters: index/identifier of the (pre)configured codebook.

[0212] For example, using non-consecutive rows, or columns based approach, codebook elements may comprise any of the following parameters: list of indexes of columns, list of indexes of rows. One or more (e.g., each) index points to specific row or column in a look-up codebook. Codebook elements may comprise any of the following parameters: index/identifier of the (pre)configured codebook.

[0213] Codebook elements may be defined by any of the following parameters: index/identifier of the (pre)configured codebook.

[0214] Codebook elements may be defined by any of the following parameters: identifier/Index to a codebook known to the WTRU (e.g., UE) for e.g. (pre)configured into the WTRU (e.g., UE).

[0215] Codebook elements may be defined by any of the following parameters: identifier/index to a sub-codebook within a codebook known to the WTRU (e.g., UE) for e.g. (pre)configured into the WTRU (e.g., UE). In this approach, a codebook may be composed of several sub-generator codebooks, where a sub-codebook is made of a subset of rows and subset of columns within the set of rows and columns respectively, of a codebook. Elements (coding coefficients/symbols) of the codebook, may be drawn from the corresponding GF (with symbol size (s) size as defined in

previous sections or as described herein in other sections are explicitly (pre)configured into the WTRU (e.g., UE)

[0216] The following list of configurable and/or controllable parameters e.g., shaping operation/performance characteristics (e.g., Network coding Techniques/Modes related inputs) may be defined: (1) fixed rate; (2) rateless; (3) code rate type; (4) fixed block coding; (5) sliding window coding; (6) block coding type; (7) transparent mode; (8) transparent mode or non-transparent mode; (9) feedback based; (10) non-feedback based; (11) feedback or non-feedback; (12) adaptive mode;

[0217] (13) non-adaptive mode; (14) adaptive or non-adaptive; (15) coherent mode; (16) non-coherent mode; (17) coherent or non-coherent; (18) codebook mode; (19) non-codebook mode; (20) codebook or non-codebook; (21) GF arithmetics look-up; (22) Online GF arithmetics; (23) GF arithmetic look-up or online GF arithmetics; (24) duplication; (25) NC SDUs segmentation based NC; (26) NC SDUs concatenation based NC; (27) NC SDUs hybrid NC SDUs segmentation or concatenation based NC; and (28) NC SDU grouping (SG).

[0218] Fixed rate: true or false, 1 or 0; true or 1 indicating a fixed code rate should be used, false or 0 indicating a fixed code rate should not be used or a rateless code should be use, or vice-versa.

[0219] Rateless: true or false, 1 or 0; true or 1 indicating if a rateless code should be used, false or 0 indicating a rateless code should not be used or a fixed code rate should be used, or vice-versa.

[0220] Code rate type: fixed rate code indicating fixed code rate should be used, rateless code indicating rateless code should be used, or vice-versa.

[0221] Fixed block coding: true or false, 1 Or 0; true or 1 indicating a fixed block coding should be used, false or 0 indicating a fixed block coding should not be used or a sliding window coding should be used, or vice-versa.

[0222] Sliding window coding: true or false, 1 or 0; true or 1 indicating a sliding window block coding should be used, false or 0 indicating a sliding window coding should not be used or a fixed block coding should be used, or vice-versa.

[0223] Block coding type: fixed block coding indicating fixed block coding should be used, sliding window coding indicating sliding window coding should be used, or vice-versa.

[0224] Transparent mode: true or false 1 or 0; true or 1 indicating transparent mode should be used, false or 0 indicating transparent mode should not be used, or vice versa. As specified in this disclosure, transparent mode may be configured at the level of control granularity defined in this disclosure including bearer level, RLC bearer level, NC PDU bearer level, etc.

[0225] Transparent mode or non-transparent mode possible values may be transparent mode, non-transparent mode.

[0226] Feedback based: true or false, 1 or 0; true or 1 indicating feedback-based NC should be used, false or 0 indicating feedback based NC should not be used or non-feedback based NC should be used, or vice-versa.

[0227] Non-feedback based: true or false, 1 or 0; true or 1 indicating non-feedback-based NC should be used, false or 0 indicating non-feedback based NC should not be used or feedback based NC should be used, or vice-versa.

[0228] Feedback or non-feedback – possible values: feedback mode, non-feedback mode.

[0229] Adaptive mode: true or false, 1 or 0; true or 1 indicating adaptive NC should be used, false or 0 indicating adaptive NC should not be used or non-adaptive NC should be used, or vice-versa.

[0230] Non-adaptive mode: true or false, 1 or 0; true or 1 indicating non-adaptive NC should be used, false or 0 indicating non-adaptive NC should not be used or adaptive NC should be used, or vice-versa.

[0231] Adaptive or non-adaptive - possible values: adaptive mode, non-adaptive mode.

[0232] Coherent mode: true or false, 1 or 0; true or 1 indicating coherent NC should be used, false or 0 indicating coherent NC should not be used or non-coherent should be used, or vice-versa.

[0233] Non-Coherent mode: true or false, 1 or 0; true or 1 indicating non-coherent NC should be used, false or 0 indicating non-coherent NC should not be used or coherent NC should be used, or vice-versa.

[0234] Coherent or non-coherent – possible values: coherent mode, non-coherent mode.

[0235] Codebook mode: true or false, 1 or 0; true or 1 indicating codebook based NC should be used, false or 0 indicating codebook based NC should not be used or non-codebook based NC should be used, or vice-versa.

[0236] Non-codebook mode: true of false, 1 or 0; true or 1 indicating non-codebook -based NC should be used, false or 0 indicating non-codebook based NC should not be used or codebook based NC should be used, or vice-versa.

[0237] Codebook or non-codebook possible values may be codebook, non-codebook.

[0238] GF arithmetics look-up: true or false, 1 or 0; true or 1 indicating GF arithmetics look-up table based NC should be used, false or 0 indicating GF arithmetics look-up table based NC should not be used or online GF arithmetics based NC should be used, or vice-versa.

[0239] Online GF arithmetics: true or false, 1 or 0; true or 1 indicating online GF arithmetics based NC should be used, false or 0 indicating online GF arithmetics should not be used or GF arithmetics look-up table based NC should be used, or vice-versa.

[0240] GF arithmetic look-up or online GF arithmetics possible values may be GF arithmetic look-up, online GF arithmetics.

[0241] Duplication: true or false, 1 or 0; true or 1 indicating duplication or repetition or copy based NC should be used, false or 0 indicating duplication or repetition or copy based NC should not be used, or vice-versa.

[0242] NC SDUs segmentation based NC: true or false, 1 or 0; true or 1 indicating NC SDUs segmentation based NC should be used, false or 0 indicating NC SDUs segmentation based NC should not be used or NC SDUs concatenation based NC should be used, or vice-versa.

[0243] NC SDUs concatenation based NC: true or false, 1 or 0; true or 1 indicating NC SDUs concatenation based NC should be used, false or 0 indicating NC SDUs concatenation based NC should not be used or NC SDUs segmentation based NC should be used, or vice-versa.

[0244] NC SDUs hybrid NC SDUs segmentation or concatenation based NC: true or false, 1 or 0; true or 1 indicating hybrid NC SDUs segmentation or concatenation based NC should be used, false or 0 indicating hybrid NC SDUs segmentation or concatenation based NC should not be used, or vice-versa.

[0245] NC SDU grouping (SG) possible values may be NC SDUs segmentation, NC SDUs concatenation, hybrid NC SDUs segmentation or NC SDUs concatenation.

[0246] The following list of configurable and/or controllable parameters e.g., shaping NC context management may be defined: (1) NC context control; (2) activation/deactivation; (3) conditions to start encoding; and (4) conditions to start decoding.

[0247] NC Context control may be defined by a length or maximum value for NC Context ID (# context "in-flight") per NC entity. NC Context control May be aligned to NC upper layer protocol sequence number e.g., the sequence number of the NC SDUs for example in case of NC SDU segmentation based NC. For example, in the case of NC SDU segmentation based NC, if NC is implemented by PDCP sublayer or between PDCP sublayer and RLC sublayer, the length/maximum value of NC context ID may be aligned to the PDCP SN, i.e., there is one-to-one mapping between PDCP SDU SN and NC Context ID. In the case of fixed block coding (segmentation or concatenation based NC), the length or maximum value for the NC context ID may be aligned with the generation sequence number. For example, if pre-NC PDU set (NC upper layer protocol PDU set) is used as generation of packets for NC, the length of maximum value of NC Context ID may be aligned with the length/maximum value of pre-NC PDU set SN (sequence number). Similarly, in the case of sliding window coding (segmentation or concatenation based NC), the length or maximum value for the NC context ID may also be aligned with the generation sequence number. A special case is a case where there is (e.g., only) one sliding window for

example when consecutive sliding windows always have overlapping packets. In such case, there could be (e.g., only) one NC context, e.g., maximum value of NC context ID is 0 is starting number of the numbering of NC context ID is 0. The length of NC context ID may be expressed in number of bits. The maximum value of NC context ID can (e.g., then) be expressed as $2^{CL} - 1$, where CL is the length of the NC context ID in bit.

[0248] The minimum value of NC Context ID may be 0.

[0249] About length or maximum value of iteration of NC (NC_count) in an NC context, the length of NC_count may be expressed in number of bits. The maximum value of NC_count can (e.g., then) be expressed as $2^{NC_count} - 1$, where NC_count is the length of the NC_count in bits. The minimum value of NC_count may be 0.

[0250] Value for the timer to control the lifetime of an NC Context; could be an enumerated set of values: maximum value/minimum value; the maximum and minimum values may be configured in support for example for dynamic control of NC Processing at the WTRU (e.g., UE); default, initial, or target value.

[0251] Activation/Deactivation: the WTRU (e.g., UE) may determine to activate, deactivate NC processing for a given NC entity, NC context, associated radio bearer, associated PDU set, associated differentiated handling/processing autonomously based on one or more criteria which criteria may be a configuration aspect of the WTRU (e.g., UE) and/or upon reception of signaling indicating (de-)activation. The WTRU (e.g., UE) may be configured to that effect.

[0252] The list of configurable and/or controllable parameters e.g., shaping NC context management may comprise parameters related to NC PDU L3 bearer level activation/deactivation e.g., PDCP bearer (or simply bearer) level activation/deactivation.

[0253] The list of configurable and/or controllable parameters e.g., shaping NC context management may comprise parameters related to NC PDU L2 bearer level activation e.g., RLC bearer/leg or logical channel level activation/deactivation.

[0254] The list of configurable and/or controllable parameters e.g., shaping NC context management may comprise parameters related to NC PDUC L1 bearer level activation, e.g. HARQ entity bearer level activation/deactivation, Cell group level activation/deactivation, CC level activation/deactivation, BWP level activation/deactivation, CG type level activation/deactivation, configured grant configuration level activation/deactivation, resource pool level activation/deactivation, DG level activation/deactivation, beam level activation/deactivation, TRP level activation/deactivation, frame level activation/deactivation, timeslot level activation/deactivation, mini-time slot activation/deactivation, pre-configured time instants level activation/deactivation.

[0255] When network (e.g., base station) or a peer or remote entity (e.g. receiver or decoder) makes the activation or deactivation decision, one or more (e.g., each) of the activation/deactivation level defined above may be done via MAC CE signaling, DCI signaling, PDCP control PDU signaling, RLC control PDU level signaling, for example as a function of the placement in the air interface protocol layers, of the function that makes the activation or deactivation decision. For example, if the activation or deactivation decision functional is located in MAC, a MAC CE signaling may be used. If the decision is made at the PHY layer, a DCI signaling may be used. If the decision is made in PDCP layer, a PDCP control PDU signaling may be used.

[0256] Conditions to start encoding: the WTRU (e.g., UE) may determine when to apply NC processing to one or more SDUs as a function of e.g., a buffer reporting status criteria (e.g., when data become available for transmission), when one or more (e.g., all) SDUs for the same set are available for NC processing, when (or a specified time boundary) the WTRU (e.g., UE) determines that resources may be available for transmission for at least some of the resulting NC-processed SDUs, a sliding window state, etc. The WTRU (e.g., UE) may be configured to that effect.

[0257] The WTRU (e.g., UE) may be configured with conditions to start encoding, when NC SDUs become available in the WTRU (e.g., UE) TX buffer. The control may be at the level of any of the control granularity described in this disclosure, for example as a function of QoS/bearer level configuration. For example, in the case where NC SDUs are concatenated as part of a NC SDU set (i.e., pre-NC PDU set), the WTRU (e.g., UE) may be configured to start NC encoding as soon as an NC SDU of the NC SDU set becomes available at the WTRU (e.g., UE) TX buffer. Specifically, for concatenation based NC, the WTRU (e.g., UE) may be configured to start NC encoding as soon as an NC SDU within an NC SDU set becomes available at the WTRU (e.g., UE) TX buffer (e.g. this NC SDU can be segmented to get the NC encoding process started), or two or more NC SDU with the NC SDU set becomes available, or a threshold based for e.g. absolute value, or percentage of the number of NC SDU part of the NC SDU set become available at the WTRU (e.g., UE) TX buffer. In another alternative, the WTRU (e.g., UE) may be configured to start encoding (e.g., only) when one or more (e.g., all the) NC SDUs of the NC SDU set become available. The WTRU (e.g., UE) uses this NC control information to decides its readiness for encoding processing, e.g., whether or not to start the encoding operation. More generally, the WTRU (e.g., UE) may be configured to start NC encoding as soon as an NC SDU of the packet generation (or encoding window) becomes available at the WTRU (e.g., UE) TX buffer. Specifically, for concatenation based NC, the WTRU (e.g., UE) may be configured to start NC encoding as soon as an NC SDU within the generation (or encoding window) for this NC context

becomes available at the WTRU (e.g., UE) TX buffer, or two or more NC SDU within the generation become available, or a threshold based for e.g. absolute value, or percentage of the number of NC SDUs of the generation becomes available at the WTRU (e.g., UE) TX buffer. In another alternative, the WTRU (e.g., UE) may be configured to start encoding (e.g., only) when one or more (e.g., all the) NC SDUs of the generation become available. The WTRU (e.g., UE) uses this NC control information to decides its readiness for encoding processing, e.g., whether or not to start the encoding operation.

[0258] Conditions to start decoding: the WTRU (e.g., UE) may determine when to decode one or more received NC-processed PDU as a function of e.g., reception of the concerned one or more PDUs, reception of a PDU for a specific NC context, when one or more (e.g., all) PDUs associated to the same PDU set are available for NC processing, when (or a specified time boundary) such as determined from a sliding window state etc. The WTRU (e.g., UE) may be configured to that effect. The WTRU (e.g., UE) may be configured with conditions to start decoding, when NC PDUs become available in the WTRU (e.g., UE) TX buffer. The control may be at the level of any of the control granularity described in this disclosure, for example as a function of QoS/bearer level configuration. For example, in the case where NC SDUs are concatenated as part of a NC SDU set (i.e., pre-NC PDU set), the WTRU (e.g., UE) may be configured to start NC decoding as soon as an NC PDU associated with an NC context becomes available at the WTRU (e.g., UE) RX buffer. Specifically, for concatenation based NC, the WTRU (e.g., UE) may be configured to start NC decoding as soon as an NC PDU associated with an NC context becomes available at the WTRU (e.g., UE) RX buffer, or two or more NC SDUs associated with the NC context become available, or a threshold based for e.g. absolute value, or percentage of the number of NC PDU expected for this NC context become available at the WTRU (e.g., UE) RX buffer. In another alternative, the WTRU (e.g., UE) may be configured to start decoding (e.g., only) when one or more (e.g., all the) NC PDUs associated with the NC context become available. The WTRU (e.g., UE) uses this NC control information to decides its readiness for NC decoding processing, e.g., whether or not to start the decoding operation.

[0259] The following list of configurable and/or controllable parameters e.g., shaping NC output and format, for example from NC Processing for one or more (e.g., each) NC iteration may be defined by any of the following parameters: (1) Codeword; and (2) NC PDU header of NC PDU.

[0260] Codeword may be defined by parameters related to a number of coded packets from this NC iteration, accordingly to the target code rate for this NC iteration; and/or coded packets from this NC iteration, accordingly to the target code rate for this NC iteration.

[0261] NC PDU header of NC PDU may comprise any of the following information indicating: (i) coherent mode (CM) indicator field; (ii) codebook (CB) indicator field; (iii) context ID (CID) field; (iv) encoding vector (EV) field for coherent NC; (v) encoding vector (EV) field for non-coherent NC; (vi) NC SDU Grouping (SG) field; (vii) number of segments in a NC SDU, or number of NC SDU contributing to NC SDU segments in the generation.

[0262] Coherent mode (CM) indicator field: 1 bit; indicate if coherent NC is used or non-coherent NC is used. For example, 1 indicate coherent NC is used and 0 indicate non-coherent NC is used, or vice-versa. The WTRU (e.g., UE) may use an NC PDU header which doesn't include this field if the WTRU (e.g., UE) maps for transmission, the NC PDU to a NC PDU bearer dedicated to carrying coherent mode-based NC PDUs.

[0263] Codebook (CB) indicator field: 1 bit; indicates if codebook-based NC or non-codebook-based NC is used. For example, 1 indicate codebook-based NC is used and 0 indicate non-codebook based NC is used, or vice-versa. The WTRU (e.g., UE) may use an NC PDU header which doesn't include this field if the WTRU (e.g., UE) maps for transmission, the NC PDU to a NC PDU bearer dedicated to carrying codebook-based NC PDUs.

[0264] Context ID (CID) field; used by the receiving node (e.g., decoder) to identity the NC context for this NC PDU. If no context with this context ID exists, the receiving node creates a new Context for this context ID.

[0265] Encoding vector (EV) field for coherent NC with (e.g., implicit) indication of values of coding coefficients; The field includes a row index pointing to a row in a look-up generator matrix for this NC context configured into the WTRU (e.g., UE). One or more (e.g., each) row has $\tilde{K}$ columns. The field may include a starting column index, or an end column index. The length of the field may be expressed in bits or octets and should be long enough to cover the maximum expected number of columns $\tilde{K}$ in a look-up generator matrix.

[0266] Encoding vector (EV) field for non-coherent NC with explicit value of coding coefficients; The length in bits should be long enough to cover the expected maximum generation size. The field includes an ordered list of the coding coefficients, where the first coding coefficient corresponds to the first packet in the generation for this NC context, the second coding coefficient corresponds to the second packet in the generation, and so on.

[0267] Whether the encoding vector field is for coherent NC or non-coherent NC, the transmitting WTRU (e.g., UE) shall order the packets of the generation to match the order of the coding coefficients in the encoding vector. In other words, the transmitting WTRU (e.g., UE) orders the coding coefficients to match the order of the generation packets. It should be noted that

there are as many coding coefficients, as the generation size e.g., number of input packets in the generation.

[0268] For segmentation-based NC, with (e.g., only) one NC SDU contributing to the NC SDU segments as input packets of the generation for this NC context, the decoding NC entity (e.g., the peer receiving WTRU (e.g., UE) or remote receiving UE) uses the position of the coding coefficient in the encoding vector to determine the position within the original NC SDU, of a NC SDU segment of the generation, in support for example of the NC SDU reassembly. In other words, the position of a coding coefficient in an encoding vector is the position of the corresponding NC SDU segment in the original NC SDU.

[0269] For segmentation-based NC, with two or more NC SDUs contributing to the NC SDU segments as input packets of the generation for this NC context, the transmitting WTRU (e.g., UE) may in a first step order the generation input packets according to the sequence number of their corresponding NC SDUs (decreasing order or increasing order). The transmitting WTRU (e.g., UE) (e.g., then) in a second step, orders the input packets or NC SDU segments of the same NC SDU according to their position, or sequence number or segment offset (for example in bits) within their respective NC SDUs. This assumes that the WTRU (e.g., UE) orders the segments of a NC SDU into an order that is consistent with their reassembly order within the NC SDU. The decoding NC entity (e.g., the peer receiving WTRU (e.g., UE) or remote receiving UE) uses its knowledge of the number of segments in one or more (e.g., each) NC SDUs, and the position of the coding coefficients in the encoding vector to determine the position within the original NC SDU, of a NC SDU segment in the generation.

[0270] Similarly, for hybrid segmentation or concatenation based NC, the transmitting WTRU (e.g., UE) may order the generation input packets according to the sequence number of their corresponding NC SDUs (decreasing order or increasing order). The transmitting WTRU (e.g., UE) (e.g., then) orders the input packets or NC SDU segments of the same NC SDU according to their position or sequence number or segment offset (for example in bits) within their respective NC SDUs. This assumes that the WTRU (e.g., UE) orders the segments of a NC SDU into an order that is consistent with their reassembly order within the NC SDU. A non-segmented NC SDU is assumed to have (e.g., only) one NC SDU segment. The decoding NC entity (e.g., the peer receiving WTRU (e.g., UE) or remote receiving UE) uses its knowledge of the number of segments in one or more (e.g., each) NC SDUs, and the position of the coding coefficients in the encoding vector to determine the position within the original NC SDU, of a NC SDU segment in the generation.

[0271] The decoding WTRU (e.g., UE) may determine the number of NC SDU segments within an NC SDU, or the number of NC SDUs contributing to NC SDU segments of a generation: (a) dynamically based on the knowledge of one of the two parameters; (b) dynamically based on the NC PDU bearer associated with the NC PDU; and/or (c) through configurations.

[0272] Determining the number of NC SDU segments within an NC SDU, or the number of NC SDUs contributing to NC SDU segments of a generation may be dynamically based on the knowledge of one of the two parameters e.g., either number of NC SDU segments within an NC SDU, or the number of NC SDUs contributing to NC SDU segments of a generation. In this case the decoding WTRU (e.g., UE) can determine the missing parameter based on its knowledge of the generation size. Note: This NC SDUs have the same number of NC SDU segments.

[0273] Determining the number of NC SDU segments within an NC SDU, or the number of NC SDUs contributing to NC SDU segments of a generation may be dynamically based on the NC PDU bearer associated with the NC PDU, and prior network configuration.

[0274] Determining the number of NC SDU segments within an NC SDU, or the number of NC SDUs contributing to NC SDU segments of a generation may be through configurations for example with control plane signaling e.g., RRC signaling, or user plane signaling e.g., MAC CE, PDCP control PDU, RLC control PDU, DCI, etc.

[0275] NC SDU Grouping (SG) field may comprise 1 bit; indicates segmentation-based NC, or concatenation based NC; and/or 2 bits; indicates segmentation-based NC, or concatenation based NC, or hybrid segmentation or concatenation based NC.

[0276] NC PDU header of NC PDU may comprise information indicating a number of segments in a NC SDU, or number of NC SDU contributing to NC SDU segments in the generation.

[0277] For one or more (e.g., each) NC SDU, number of NC SDU segments contributed to the generation.

[0278] Note: as defined in previous sections or as described herein in other sections, one or more (e.g., all) input packets of a generation are of the same size e.g., same number of symbols or bits. When forming a generation, the transmitting WTRU (e.g., UE) may add padding bit one of the packets in the generation, to ensure equal size input packets.

[0279] Instead of relying on explicit signaling, the WTRU (e.g., UE) may determine implicitly some of the information necessary to process NC SDUs and/or NC PDUs. For example, it can determine an Implicit NC header derivation via control plane signaling. It should be noted that one or more of the header fields described in this document may not be part of an NC header. The decoding WTRU (e.g., UE) may implicitly derive one or more of the values of the header fields described in this disclosure, based on (pre)configurations received from the base station that

associates these header information for example in any combination to NC PDU bearers. In such specification options, the WTRU (e.g., UE) derives these header information based on these pre-association with NC PDU bearers. As part of the base station configuration of the WTRU (e.g., UE), the WTRU (e.g., UE) may receive semi-statically these header associations to NC PDU bearers from the base station through RRC signaling. Alternatively, the WTRU (e.g., UE) may receive these associations in a first step from the base station in RRC message, these header associations to NC bearers are (e.g., then) dynamically activated through L2 signaling for example MAC CE, DCI, PDCP control PDU, RLC control PDU, SCI, etc.

[0280] The WTRU (e.g., UE) may be configured to apply QoS differentiation of NC-processed PDUs according to different methods e.g., applying duplication, routing PDUs across different paths by assigned different PDUs of a given NC context, PDU set to different paths, etc.

[0281] The Assignment of NC PDUs to NC PDU bearer for transmission may take into account any of the following parameters: maximum number of NC PDU bearers (e.g., # L3 bearer, # L2 bearer, # L1 bearer, # RLC bearer/leg, # CC, # sets of coded blocks from the same NC iteration for transmission at different time.).

The WTRU (e.g., UE) may perform allocation of coded packets to NC PDU bearer based on split of the NC PDUs: (1) equal split as a function of NC PDU bearers activated for NC; (2) rule based split, e.g., based on the configuration (e.g., NC PDU L1 bearer configuration or NC PDU L2 bearer configuration) of the NC PDP bearer activated for NC. For example, assuming NC is implemented in PDCP, the WTRU (e.g., UE) may assign NC PDU to RLC entity as a function of the grant type (Type 1, Type 2, or DG), or resource configuration associated with the MAC entity for this RLC entity; (3) threshold based split (e.g., thresholds may be configured into the WTRU (e.g., UE). The WTRU (e.g., UE) may determine the number of activated NC PDU bearers to be used as a function of the thread and assign/submit equally or as a function of pre(configured) proportion, the NC PDUs to activated NC PDU bearers).

[0282] The WTRU (e.g., UE) may perform allocation of coded packets to NC PDU bearer based on duplication of the NC PDUs: (1) full duplication: one or more (e.g., all) available NC PDUs from this NC iteration are duplicated across a number of transmission bearers; (2) partial duplication: a subset of one or more (e.g., all) available NC PDUs from this NC iterations is duplicated across a number of transmission bearers.

[0283] Transmission of NC PDUs and duplicated copies of the same NC PDUs may be in same order, on their respective NC PDU bearers (e.g., RLC legs/bearers).

[0284] Transmission of NC PDUs in a given order, and transmission of duplicated copies of the same NC PDUs may be in the reverse order, on their respective NC PDU bearers (e.g., RLC legs/bearers).

[0285] The WTRU (e.g., UE) may perform allocation of NC PDUs to NC PDU bearers on per NC PDU set basis or per NC PDU basis as specified in previous sections or as described herein in other sections.

[0286] The term NC PDU bearer may be used herein in reference to the terms transmission path, transmission profile or post-NC TX bearer. Similarly, the term NC PDU bearer may be further used in reference to the terms receive path, receive profile or pre-NC RX bearer. A NC PDU bearer may be defined in terms of one or more of Layer-3 (L3) bearer, Layer-2 (L2) bearer, and Layer-1 (L1/PHY) bearer, at least as a function of the placement of network coding function in the air interface protocol stack. A WTRU (e.g., UE) may treat two NC PDU bearers as different bearers if the two NC PDU bearers differ by at least one of their attributes/characteristics, as defined below by means of the definition of NC PDU L1 bearer, NC PDU L2 bearer, and L3 NC PDU bearer.

[0287] Differentiated handling per NC PDU SET

[0288] The WTRU (e.g., UE) may determine that NC PDUs that include NC-processed data associated to the same SDU belong to an NC PDU set. The WTRU (e.g., UE) may assign sequencing, identification information for one or more (e.g., each) NC PDU of the NC PDU set and/or within the header of the resulting MAC PDU. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given NC PDU set as part of MAC layer processing. Differently expressed, the WTRU (e.g., UE) may apply the same treatment/handling to the NC PDUs within the same NC PDU set, and/or may apply different treatment/handling to the NC PDUs from different NC PDU sets. A special case is when NC PDU set size is 1, in this case the WTRU (e.g., UE) may treat/handle one or more (e.g., each) NC PDU differently.

[0289] The following describe solutions for multiplexing and selecting data to be included in transport blocks when the WTRU (e.g., UE) uses network coding. Such solutions may maximize performance benefit of network coding by enabling transmission of network-coded PDUs over channels that have low or no mutual correlation.

[0290] A WTRU (e.g., UE) may determine that first and second MAC PDUs contains first and second network-coded (NC) PDUs, respectively, or segments thereof, wherein first and second network-coded PDUs are generated from network encoding of a same data block (SDU). Such first and second network-coded PDUs may be said to belong to a "network-coded PDU set" or "NC PDU set" in the following. In the following, the term "PDU" may be used to refer to a PDU of a NC PDU set, or a segment of such PDU.

[0291] The WTRU (e.g., UE) may associate any of the following information (e.g., NC PDU set information) to one or more (e.g., each) NC PDU: (1) an identifier or sequence number of a NC PDU set the PDU belongs to; (2) a first identifier or sequence number of the PDU within a NC PDU set, wherein at most one PDU may be associated to the identifier; and (3) a second identifier associated to one or more (e.g., each) PDU, wherein more than one PDU may be associated to the identifier.

[0292] The WTRU (e.g., UE) may include such information in at least one field in the header of a PDU and/or of a segment thereof.

[0293] The WTRU (e.g., UE) may apply differentiated handling of PDUs that have been processed by NC coding per PDU or per set of PDUs using one or more criteria e.g., PDU size. In term of assignment of NC PDUs to NC PDU bearer, the WTRU (e.g., UE) may assign NC PDU to NC PDU bearers on per-NC PDU set basis. One embodiment of per-NC PDU set based assignment of NC PDUs to NC PDU bearers' assignment, is the case where the grouping of NC PDUs into PDU sets comprises of equal size NC PDU sets of size 1. In this case, the WTRU (e.g., UE) assigns NC PDUs to NC PDU bearers on per NC-PDU basis.

[0294] The WTRU (e.g., UE) may apply differentiated handling of PDUs that have been processed by NC coding per PDU or per set of PDUs using one or more criteria e.g., semi-static configuration. The WTRU (e.g., UE) may determine grouping of NC PDUs into NC PDU sets semi-statically for example based on configuration received e.g., from L3, L2 signaling and/or configuration received from a serving base station, a peer receive node or a remote node, or based on predefined rules for example captured in the specification.

[0295] The WTRU (e.g., UE) may apply differentiated handling of PDUs that have been processed by NC coding per PDU or per set of PDUs using one or more criteria e.g., dynamic signaling and/or UE-autonomous criteria. Alternatively, the WTRU (e.g., UE) may determine grouping of NC PDUs dynamically, for example based on dynamic command from the serving base station, peer receive node or remote receive node e.g., from the reception of L3, L2 or L1 signaling. Alternatively, the WTRU (e.g., UE) may autonomously determine grouping of NC PDUs dynamically, for example based on or more of configurations available at the WTRU (e.g., UE), radio conditions (e.g., channel quality, load conditions, etc.), or NC PDU bearers (as defined in this disclosure) that can be used for the transmission of available NC PDUs.

[0296] The WTRU (e.g., UE) may apply differentiated handling of PDUs that have been processed by NC coding per set of PDUs e.g., first grouping PDUs based on criteria and (e.g., then) applying the differentiation based on the group. One possible criterion for grouping and/or for differentiation of the one or more PDU(s) may include one or more radio conditions.

[0297] The WTRU (e.g., UE) may make decision of assignment of NC PDUs to NC PDU bearers on per-NC PDU set basis, semi-statically, e.g., where the assignment decision is based for example on configurations semi-statically configured into the WTRU (e.g., UE).

[0298] Alternatively, the WTRU (e.g., UE) makes decision of assignment of NC PDUs to NC PDU bearer on per-NC SDU set basis, dynamically, e.g., where the assignment decision is based on for example one or more of, configurations available at the WTRU (e.g., UE), radio conditions (e.g., channel quality, load conditions, etc.), or NC PDU bearers (as defined in this disclosure) that can be used for the transmission of available NC PDUs. In another alternative, the WTRU (e.g., UE) makes decision of assignment of NC PDUs to NC PDU bearers on per-NC PDU set basis dynamically, for example based on dynamic command from the network, or peer WTRU (e.g., UE), or remote WTRU (e.g., UE) (e.g., MAC CE, PHY DCI/SCI). One embodiment of per-NC PDU set assignment to NC PDU bearer decision is the case where the grouping of NC PDUs into PDU sets comprises of equal size NC PDU sets of size 1. In this case, the decision for NC PDU assignment to NC PDU bearers is on per NC PDU basis.

[0299] Differentiated handling, physical layer processing

[0300] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of PHY layer processing e.g., either a) spread PDUs of a same NC PDU set over different, possibly determined by configuration, diversity path based on a differentiation for one or more parameters (e.g., related to time, space, frequency or code) or restrict one or more (e.g., all) of those PDUs to a single diversity path or b) perform such determination based on explicitly received signaling, which signaling may possibly override other UE-autonomous determination of how to apply mapping of a PDU to a diversity path.

[0301] The following describe solutions for multiplexing and selecting data to be included in transport blocks when the WTRU (e.g., UE) uses network coding. Such solutions may maximize performance benefit of network coding by enabling transmission of network-coded PDUs over channels that have low or no mutual correlation.

[0302] In some solutions, the WTRU (e.g., UE) may determine a "diversity path" associated to a grant or PUSCH. The WTRU (e.g., UE) may determine a diversity path based on at least one of following: (1) at least one other property of the grant or PUSCH; (2) Signaling from the DCI scheduling PUSCH or RRC configuration of a configured grant.

[0303] At least one other property of the grant or PUSCH may be any of the following parameters: (i) serving cell, e.g., the WTRU (e.g., UE) may receive a configuration for a diversity path associated to one or more (e.g., each) serving cell; (ii) carrier (normal or supplementary), e.g.,

the WTRU (e.g., UE) may receive a configuration for a diversity path associated to a normal carrier or a supplementary carrier of a serving cell; (iii) timing, e.g., the WTRU (e.g., UE) may receive configuration indicating a diversity path applicable to a transmission occurring within a certain time period or occasion; (iv) TCI state, e.g., the WTRU (e.g., UE) may receive configuration indicating a diversity path applicable to a TCI state.

[0304] Signaling from the DCI scheduling PUSCH or RRC configuration of a configured grant may be any of the following parameters: (i) a new or existing field of DCI, or RNTI, for a dynamic grant or configured grant type 2; (ii) information element part of the RRC configuration of a configured grant; (iii) a property of the PDCCH carrying the DCI, such as DCI size, search space identity, coreset, scheduling carrier, etc.

[0305] The WTRU (e.g., UE) may be configured to apply differentiated handling of one or more PDUs processing with network coding (e.g., LPC) at the physical layer, e.g., by selecting specific L1 resources (time, space, frequency) and/or transmission methods (waveform, MIMO/beamforming technique, scheduling method). In another example, an L1 component of a NC PDU bearer i.e. NC PDU L1 bearer may include one or more of time domain transmission resources (e.g. symbol of a waveform such as OFDM symbol, mini-timeslot, timeslot, radio frame, etc.), frequency domain transmission resources (e.g. component carrier, BWP, resource pool, subcarrier, resource element i.e. one subcarrier during one symbol, resource block, i.e. a number of subcarriers not confined to a unit of time e.g. NR case, or confined to a unit of time, e.g. LTE case with timeslot being the unit of time), resource grant (for e.g. in time and frequency domain), resource grant type (e.g. configured granted (CG), CG Type 1, CG Type 2, dynamic grant(DG)), grant priority, spatial domain resources (e.g. cell group e.g. MCG, SCG, mTRP/TRP, beam/TCI configuration, TCI state, etc.), code domain resources, modulation and coding scheme (MCS) selection, Tx power/TX power level.

[0306] Differentiated handling, Layer 2 processing

[0307] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., a) either spread PDUs of a same NC PDU set over different, possibly determined by configuration, LCHs or restrict one or more (e.g., all) of those PDUs to a single LCH, b) either spread PDUs of a same NC PDU set over different, possibly determined by configuration of such multiplexing priority, TBs or give highest priority to one or more (e.g., all) of those PDU to the same TB.

[0308] The following describe solutions for multiplexing and selecting data to be included in transport blocks when the WTRU (e.g., UE) uses network coding. Such solutions may maximize

performance benefit of network coding by enabling transmission of network-coded PDUs over channels that have low or no mutual correlation.

[0309] In some solutions, the WTRU (e.g., UE) may map or assign PDUs to logical channels such that at most one PDU of a same NC PDU set belongs to given logical channel. In such case, the WTRU (e.g., UE) may determine the identity or sequence of the PDU within the NC PDU set from the LCH identity according to a mapping configured by higher layers.

[0310] In some solutions, the WTRU (e.g., UE) may map or assign PDUs to logical channels such that PDUs of a NC PDU set belong to the same logical channel.

[0311] In some solutions, the WTRU (e.g., UE) may multiplex a PDU belonging to a NC PDU set into a transport block under a condition that no other PDU belonging to same NC PDU set has already been multiplexed into same transport block.

[0312] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., map PDUs of a same NC PDU set over specific transmission resources as determined from a property of the scheduling information and/or the transmission parameters.

[0313] The following describe solutions for multiplexing and selecting data to be included in transport blocks when the WTRU (e.g., UE) uses network coding. Such solutions may maximize performance benefit of network coding by enabling transmission of network-coded PDUs over channels that have low or no mutual correlation.

[0314] In some solutions, multiplexing PDU in a transport block may be dependent on at least one property of the corresponding uplink grant or associated PUSCH(s). This may include at least any of the following properties: (1) serving cell; (2) carrier (normal UL or supplementary UL); (3) bandwidth part (BWP); (4) frequency domain resource assignment; (5) time domain resource assignment; (6) timing of the transmission; (7) sub-carrier spacing; (8) priority index; (9) transmission configuration indicator (TCI) state; (10) SRS resource set indicator; (11) SRS resource indicator (SRI); (12) HARQ process identity; (13) redundancy version; (14) modulation and coding scheme; (15) a PUSCH repetition index; (16) a PUSCH occasion within a multi-PUSCH grant; and (17) a type of grant such as configured grant type 1 or type 2, dynamic grant.

[0315] The WTRU (e.g., UE) may determine that PDUs that include NC-processed data associated to the same SDU belong to a PDU set. The WTRU (e.g., UE) may (e.g., then) apply differentiation to the PDUs of a given PDU set as part of MAC layer processing e.g., a) either spread PDUs of a same NC PDU set over different, possibly determined by configuration, LCHs or restrict one or more (e.g., all) of PDUs to a single LCH, b) either spread PDUs of a same NC

PDU set over different, possibly determined by configuration of such multiplexing priority, TBs or give highest priority to one or more (e.g., all) of PDU to the same TB.

[0316] The following describe solutions for multiplexing and selecting data to be included in transport blocks when the WTRU (e.g., UE) uses network coding. Such solutions may maximize performance benefit of network coding by enabling transmission of network-coded PDUs over channels that have low or no mutual correlation.

[0317] In some solutions, the WTRU (e.g., UE) may be configured to multiplex PDU belonging to a NC PDU set into a transport block if certain conditions are satisfied for the corresponding grant and PDU. Such conditions may be referred to as "mapping restrictions".

[0318] The WTRU (e.g., UE) may receive configuration of at least one mapping restriction for any of the following: (1) a logical channel; (2) a first identifier or sequence number of a PDU within a NC PDU set; and (3) a second identifier of a PDU.

[0319] The at least one mapping restriction may be defined by a condition such as the value of a specific grant or PUSCH property belongs to a configured set of values for the property. For example: (1) diversity path belongs to a configured set of diversity paths; (2) serving cell belongs to a configured set of serving cells; (3) carrier (normal UL or supplementary UL) is part of configured set of carriers (e.g., normal UL only, supplementary UL only, both normal UL and supplementary UL); (4) bandwidth part (BWP) is part of a configured set of BWPs; (5) frequency domain resource assignment is within a configured range of RBs; (6) timing of the transmission is within a configured set of time periods (e.g., defined as subframes or slots such that a function of subframe and/or slot number modulo a configured periodicity equals a configured offset); (7) sub-carrier spacing of PUSCH belongs to a configured set of sub-carrier spacing values; (8) priority index belongs to a configured set of priority index(es); (9) transmission configuration indicator (TCI) state for the PUSCH belongs to configured set of TCI states; (10) SRS resource set indicator belongs to a configured set of SRS resource set indicators; and (11) SRS resource indicator (SRI) belongs to a configured set of SRIs.

[0320] The at least one mapping restriction may be separately configurable for one or more (e.g., each) logical channel or one or more (e.g., each) identity or sequence number. For example, for one or more (e.g., each) identity or sequence number or logical channel, the WTRU (e.g., UE) may receive configuration of a set of allowed diversity paths, allowed set of serving cells, etc.

[0321] The allowed diversity path may correspond or be identical to the sequence number of the PDU within a NC PDU set. This means, for example, that a DCI may explicitly indicate the allowed sequence number(s) of PDU for multiplexing in the transport block. Such multiplexing restriction may apply to a PDU belonging to a NC PDU set only.

[0322] The WTRU (e.g., UE) may be configured to apply differentiated handling of one or more PDUs processed with network coding (e.g., LPC) at L2 processing e.g., by selecting specific L2 bearers, L2 instance (e.g., PDCP, RLC and/or MAC instance(s)), LCH, MAC multiplexing or processing/diversity path (possibly including enabling duplication).

[0323] In another example, an L2 component of a NC PDU bearer e.g., NC PDU L2 bearer may include one or more of: RLC leg(s)/bearer(s), allowing the WTRU (e.g., UE) to map NC PDUs (of the same NC codeword) e.g., as output packets from the NC processing of the same NC generation within the same NC iteration or across NC iterations, to the same or different RLC bearers.

[0324] One or more (e.g., each) RLC leg(s)/bearers may be configured with any of: (1) logical channels allowing the WTRU (e.g., UE) to transmit the NC PDUs from the same or different NC iteration but mapped to the same RLC bearer to be transmitted over different logical channels; (2) cell Group; (3) RLC mode; (4) buffer status reporting.

[0325] One or more (e.g., each) logical channel is configured with any of: (i) logical channel ID; (ii) logical channel priority; (iii) logical channel prioritized bit rate; allowed serving cells; (iv) allowed SCS; (v) configured grant Type 1 allowed; (vi) scheduling request ID; (vii) allowed configured grants; (viii) allowed HARQ mode; (ix) allowed HARQ redundancy version; (x) allowed PHY priority index; (xi) cell Group; (xii) logical channel group ID; (xiii) channel access priority; and (xiv) other logical channel configuration parameters.

[0326] Logical channel ID may identify this logical channel for this RLC bearer.

[0327] Logical channel priority may identify the priority of this logical channel.

[0328] Logical channel prioritized bit rate may indicate the prioritized bit rate applicable to the NC PDUs from this logical channel; NC PDUs from the same NC generation.

[0329] Allowed serving cells may comprise of a list of allowed serving cell index/ID, that the NC PDUs from this logical channel can be mapped to.

[0330] Allowed SCS may comprise a list of allowed SCSs (numerologies), that the NC PDUs from this logical channel can be mapped to. Otherwise, the NC PDUs from this logical channel can be mapped to (default) allowed SCSs for the pre-NC PDUs (associated with the NC upper layers bearer) that this RLC bearer mapped to, or the NC PDUs from this logical channel can be mapped to any configured numerology.

[0331] Configured grant Type 1 allowed may be defined by a Boolean value (true, not true or false).

[0332] Scheduling request ID may indicate the scheduling request configuration applicable for this logical channel.

[0333] Allowed configured grants (applicable when the UL grant is configured grant) may indicate the list of configured grants the NC PDUs from this logical channel can only be mapped to. Otherwise, the NC PDU from this logical channel can be mapped to (default) allowed grants for the pre-NC PDUs (associated with the NC upper layers bearer) that this RLC bearer mapped to, or the NC PDUs from this logical channel can be mapped to any configured grant configurations. If configured grant Type 1 is allowed for this logical channel, then only the configured grants of Type 1 in this list of allowed configured grants are allowed for use by this logical channel, otherwise, this list shall not include any configured grant type 1 configuration.

[0334] Allowed HARQ mode (e.g., mode A, or mode B) may indicate the allowed HARQ mode of a HARQ process mapped to this logical channel e.g., if (UL) HARQ retransmission is activated (mode A) or deactivated (mode B). If the parameter is absent, there is no restriction for HARQ mode for this mapping.

[0335] Allowed HARQ redundancy version may indicate the allowed HARQ redundancy version allowed for the TBs that includes NC PDUs from this logical channel.

[0336] Allowed PHY priority index may indicate NC PDUs from this logical channel can only be mapped to a dynamic grant whose PHY priority index equal to the values configured for this field.

[0337] Cell Group, where one or more (e.g., each) Cell group may be configured with one or more of: (i) cell group ID; (ii) one or more cells or component carriers, where one or more (e.g., each) cell or component carrier is configured with one or more of L1 transmission bearer; (iii) logical channel group ID, the identity of the logical channel group this logical channel belongs to; (iv) channel access priority, indicating the channel access priority class to be used for uplink transmission with shared spectrum channel access; and (v) other logical channel configuration parameters, for example, as defined in 38.331 or 38.321. Note: There may be one or more logical channels associated with an RLC bearer, for example as a function of the NC placement, for example, if NC is placed within RLC sublayer or between RLC and MAC, in order for the WTRU (e.g., UE) to provide differentiated treatment for NC PDUs.

[0338] One or more (e.g., each) logical channel is configured with cell Group, where one or more (e.g., each) Cell group is configured with one or more of: cell group ID; one or more cells or component carriers, where one or more (e.g., each) cell or component carrier is configured with one or more of L1 transmission bearer.

[0339] One or more (e.g., each) logical channel is configured with RLC mode, for e.g., RLC AM mode, RL UM mode, or RL transparent mode.

[0340] One or more (e.g., each) logical channel is configured with buffer status reporting, whether or not the WTRU (e.g., UE) shall consider the NC PDU header overhead in the calculation of data available for transmission for SDUs that are considered available for transmission but not yet NC processed. For example, if configured to report such amount of data information, the WTRU (e.g., UE) may include the overhead of the NC header in the calculation of the buffer status reporting e.g., for SDUs that are available for transmission but for which NC has not been applied. For example, the WTRU (e.g., UE) may determine a fixed overhead for the NC information as a function of the configuration for NC processing e.g., whether or not codebook information is included in the NC header that applies for one or more (e.g., each) NC PDU. For example, the WTRU (e.g., UE) may determine the number of NC PDU to be generated for a given SDU, and report the corresponding NC header overhead as the sum for one or more (e.g., all) PDUs for a given SDU.

[0341] Common Solution Components

[0342] The WTRU (e.g., UE) may apply multiplexing principles per NC PDU independently.

[0343] A PDU restriction may apply per NC PDU set only. In a solution, the WTRU (e.g., UE) may multiplex a first and second PDUs in first and second TB if (e.g., any of) the following conditions are satisfied: (1) First and second PDUs belong to different NC PDU sets; (2) first and second PDUs have same identifier (e.g., second identifier as defined above); and (3) first and second TBs are associated to first and second grants or PUSCHs, wherein first and second grants or PUSCHs have different diversity paths.

[0344] In a solution, the WTRU (e.g., UE) may multiplex a first and second PDUs in first and second TB if (e.g., any of) the following conditions are satisfied: (1) first and second PDUs belong to different NC PDU sets; (2) first and second PDUs are from same logical channel; and (3) first and second TBs are associated to first and second grants or PUSCHs, wherein first and second grants or PUSCHs have different diversity paths.

[0345] Above solutions may allow different mapping of logical channel to diversity path (or PDU identifier to diversity path) between different NC PDU sets. For example, for a first NC PDU set, the WTRU (e.g., UE) may map PDUs with identifiers {1, 2, 3} to TBs associated to diversity paths {1, 2, 3} respectively while for a second NC PDU set, the WTRU (e.g., UE) may map PDUs with identifiers {2, 3, 1} to TBs associated to diversity paths {1, 2, 3} respectively. The WTRU (e.g., UE) may thus multiplex a first PDU of a NC PDU set to first available TB regardless of the diversity path associated to the grant, and multiplex remaining PDUs to other TBs with different diversity paths.

[0346] A relaxation of PDU restriction may be based on latency. In a solution, the WTRU (e.g., UE) may multiplex first and second PDUs in first and second TB if a time difference between transmissions (e.g., initial transmission, or any HARQ retransmission) of first and second TBs is above a configured threshold. Such condition may apply irrespective of restrictions related to NC PDU sets and diversity paths.

[0347] The WTRU (e.g., UE) may finally transmit the resulting assembled MAC PDU or transport block according to the applicable transmission methods and parameters, as determined based on the above methods.

[0348] NC functional view and operation modeling

[0349] NC may be supported in various combinations of: (1) as part of the radio bearer processing functions (SRBs, and/or DRBs); (2) as standalone service to an existing protocol e.g., RRC, SDAP, PDCP, RLC, MAC or PHY processing; or (3) as a function within an existing protocol e.g., a function in RRC, SDAP, PDCP, RLC, MAC or PHY processing.

[0350] FIG. 6 represents one possible structure of a system overview of network coding. In the transmitting WTRU (e.g., UE) entity, the functional block includes a NC Control functional block, a Pre-NC TX Processing functional block, a TX NC processing functional block and a Post-NC TX processing functional block. Similarly, the receiving entity includes a Pre-NC RX processing functional block, a RX NC Processing functional block and a Post-NC Processing functional block. The NC Control functional block (at either the transmitting entity or the receiving entity) may be mapped into one or more of RRC layer, SDAP layer, PDCP layer, NC layer (if NC is implemented as a standalone layer), RLC layer, MAC layer, or PHY layer.

[0351] In a given protocol layer that implements one or more functions of the NC functional blocks, the protocols (e.g., peer or remote) at the transmitter and the receiver communicate with each other for the control of data processing across the user plane protocol stack, and particularly for the control of (peer or remote) NC Processing functional block, where in one embodiment, the NC processing functional block operates as a black box. The terms NC Processing functional block may be used in reference to either TX NC processing functional block or RX NC processing functional block unless otherwise specified. The same rule applies to other functional blocks of FIG.6.

[0352] Control signaling for NC function may be exchanged: (1) as part of L3/RRC signaling (e.g., for related capabilities, configuration, (de-)activation or other control aspects); (2) as control signaling a protocol where NC is applied, or which carries NC-processing PDUs (e.g., as L2/SDAP control, L2/PDCP control PDU, L2/RLC control, L2/MAC CE or L1/PHY signaling; as a standalone protocol supporting NC processing e.g., NC control PDU).

[0353] The NC Control functional block may be mapped into the air interface control plane protocol (e.g., RRC), or may be mapped into the air interface user plane protocol (e.g., PDCP, MAC, PHY, etc.), or may be mapped to a combination of control plane protocol and user plane protocol. For example, NC Control mapped to RRC sublayer controls NC Processing through RRC signaling. NC Control mapped to PDCP, MAC or PHY controls NC processing through PDCP control PDU, MAC control PDU e.g., MAC CE, or PHY signaling (e.g., DCI, UCI, or SCI). NC Control may provide control input (e.g., configuration) to NC Processing using RRC signaling, and activate or deactivate such control input through PDCP control PDU, MAC Control PDU or PHY signaling.

[0354] FIG. 7 and FIG.8 represent an example of functional views of the NC Processing functional block in FIG. 6. FIG. 7 illustrates NC Processing Functional view for NC SDU segmentation based NC coding. FIG. 8 illustrates NC Processing Functional view for NC SDU concatenation-based NC coding. The network coding processing may apply to both DRBs or SRBs. As such, the NC sublayer provides its service to its upper layer entity in the user plane. Additionally, the NC sublayer may provide its service to the RRC layer, for example if NC is placed into the PDCP layer. The following services are provided by NC to upper layers: (1) user plane data network coding; (2) control plane data network coding; and (3) data transfer.

[0355] The NC Processing functional block e.g., the protocol sublayer that implements NC Processing functional block may support any of the following functions: (1) transfer of data (user plane, or control plane for example if upper layer of NC is in control plane for example RRC); (2) maintenance of (parallel) NC contexts and NC context identities/sequence numbers; (3) mapping of NC SDU to NC context; (4) mapping of NC PDUs to NC SDU; (5) maintenance of NC coding iteration (sequence) numbers per NC context (e.g., in support of rateless coding); (6) encoding and decoding of NC SDUs; (7) segmentation and reassembly of NC SDUs in support of segmentation based NC coding; (8) determination of NC SDU set(s) (pre-NC PDU set(s)) as input packet to the NC encoding process in support of concatenation based coding; (9) routing of NC PDUs; (10) timer based or NC iteration based NC SDU discard; (11) fallback between NC and packet duplication; (12) NC re-establishment and/or service continuity (for example during mobility); and (13) NC mode of operations (e.g., adaptive NC, feedback based NC, coherent vs non-coherent based NC, codebook vs non-codebook based operation).

[0356] One example realization by having one NC entity with one or more NC context(s)/process(es), with one context/process per set of one or more SDUs possibly created based on specific indications e.g., from the served layer.

[0357] FIG. 9 represents a model for NC operation, where the WTRU (e.g., UE) maintains a number of parallel NC contexts or processes within an NC entity. In this document, the terms NC process and NC context are used interchangeably in the sense that one or more (e.g., each) NC process has one NC context. An NC context is defined by an NC context information.

[0358] The encoding WTRU (e.g., UE) maintains as part of an NC context information, one or more of the following: (1) a context identifier (context ID) or context sequence number; (2) a generator matrix; (3) a generator matrix ID; (4) a NC generation (NC SDU segments or group of NC SDUs being jointly coded together e.g., encoding windows as defined in previous sections or as described herein in other sections); (5) a NC generation sequence number; (6) NC PDUs; (7) a mapping between NC SDUs and NC PDUs (e.g., using their respective sequencing information); (8) the current value of NC iteration; (9) a maximum number of NC iterations; and (10) a maximum time value to control the lifetime of an NC context e.g., the WTRU (e.g., UE) may release the NC context at the expiration of the maximum time value e.g., including the set of applicable parameters such as timers, constants and variables associated with the NC encoding processing of the NC generation.

[0359] The WTRU (e.g., UE) may maintain one NC context per NC generation, and a generation sequence number per generation. The WTRU (e.g., UE) may instantiate an NC context at the time of the creation of NC generation e.g., when the NC entity receives an input packet from upper layers, which indicates the creation of a new NC generation, for example, when the NC entity determines that the new input packet doesn't belong to any existing NC generation.

[0360] The WTRU (e.g., UE) may update the NC context information during the course of the NC processing (i.e. over the iterations of network coding processing associated with the NC context), for example when an input packet doesn't indicate a creation of a new NC generation, i.e. is mapped/added to the NC generation, or a new coded packet is generated, or a new row is added to the generator matrix, or a row is removed from the generator matrix, or a feedback is received from the receiver indicating successful recovery of an input packet (NC SDU).

[0361] The WTRU (e.g., UE) may release/delete an NC context, for example after indication from the decoding WTRU (e.g., UE) that one or more (e.g., all the) packets of the corresponding generation have been successfully decoded, or at the expiry of a timer. The WTRU (e.g., UE) (re)starts such a timer at the creation of the context, or at the update of the context.

[0362] The decoding WTRU (e.g., UE) maintains as part of an NC context information, one or more of the following: (1) a context identifier (context ID) or context sequence number; (2) a generator matrix; (3) a generator matrix ID; (4) a NC generation (NC SDU segments or group of NC SDUs being jointly coded together e.g., encoding windows as defined in previous sections or

as described herein in other sections); (5) a NC generation sequence number; (6) a decoding window e.g., as defined in previous sections or as described herein in other sections; (7) a decoding window sequence number; (8) the NC PDUs, mapping between NC SDUs and NC PDUs; (9) the current value of NC iteration; and (10) the set of parameters including timers, constants and variables associated with the NC encoding processing of the NC generation.

[0363] The WTRU (e.g., UE) may maintain one NC context per NC generation or encoding window, and a generation sequence number per generation or encoding window. The decoding WTRU (e.g., UE) may instantiate an NC context at the time of the creation of NC generation or encoding window e.g., when the NC entity receives an NC PDU from lower layers, which indicates the creation of a new NC context, for example the context ID in the NC PDU header doesn't match the ID of any existing context at the decoder.

[0364] The WTRU (e.g., UE) may update the NC context information during the course of the NC processing (for e.g., over the iterations of network decoding processing associated with the NC context), for example when the NC entity receives an NC PDU from lower layers, which doesn't indicate a creation of a new NC generation or encoding window, for example the context ID in the NC PDU header matches the ID of an existing context at the decoder.

[0365] The decoding WTRU (e.g., UE) may release/delete an NC context, for example after successful decoding of the corresponding generation packets, or at the expiry of a timer. The WTRU (e.g., UE) may (re)start such timer at the creation of the context, or at the update of the context.

[0366] The WTRU (e.g., UE) may be configured with an association between a NC context and a QoS processing path e.g., one or more of a L2/L1 processing step, a DRB, a LCH and/or specific transmission resources. The encoding WTRU (e.g., UE) may map, the NC PDUs from the same NC process or NC context to the same or different transmit/transmission paths, or transmission profiles, or post-NC TX bearers for transmission. The decoding WTRU (e.g., UE) may receive the NC PDUs from the same NC process or context from the same or different receive paths, or receive profiles, or post-NC RX bearers. There may be a one-to-one mapping between the terms transmission path, or transmission profile, or post-NC TX bearer (from the transmitter perspective), and the terms receive path, receive profile or pre-NC RX bearer respectively (from the receiver perspective). In one example realization, there may be an association between the uplink and downlink processing such that the terms path, profile or bearer may further refer to bidirectional operations.

[0367] The sequence of PDUs created as a consequence of NC processing may be treated for transmission as part of the normal radio bearer treatment, or using new methods for differentiated

handling derived from the specific characteristics of the network-coded PDUs. Differentiated handling may include subsequent L3/L2/L1 processing including mapping to specific transmission methods and resources. Expressed differently: another way to conceptualize "NC PDU bearer" is "differentiated processing/handling/treatment for LCP-processed PDUs based on characteristics of such PDUs".

[0368] For simplicity, the term NC PDU bearer may be used hereinafter in reference to the terms transmission path, transmission profile or post-NC TX bearer. Similarly, the term NC PDU bearer may be further used in reference to the terms receive path, receive profile or pre-NC RX bearer. A NC PDU bearer may be defined in terms of one or more of Layer-3 (L3) bearer, Layer-2 (L2) bearer, and Layer-1 (L1/PHY) bearer, at least as a function of the placement of network coding function in the air interface protocol stack. A WTRU (e.g., UE) may treat two NC PDU bearers as different bearers if the two NC PDU bearers differ by at least one of their attributes/characteristics, as defined below by means of the definition of NC PDU L1 bearer, NC PDU L2 bearer, and L3 NC PDU bearer.

[0369] Examples of NC PDU header

[0370] FIG. 10 illustrates an example of coherent NC PDU header. FIG. 11 illustrates another example of coherent NC PDU header. In FIG. 14, it is assumed whether NC is coherent NC or non-coherent NC is configured into the WTRU (e.g., UE) separately (for example via RRC configuration), while in FIG. 11, whether NC is coherent NC or non-coherent NC is indicated to the peer NC entity in NC PDU header. Both FIG. 10 and FIG. 11 apply to either NC SDU segmentation-based network coding or NC SDU concatenation based network coding. FIG. 11 also assumes there will be some exchange of control messages between NC peer entities.

[0371] FIG. 12 illustrates an example of non-coherent NC PDU header (NC SDU segmentation-based NC). FIG. 13 illustrates another example of non-coherent NC PDU header (NC SDU segmentation-based NC). In FIG. 12, it is assumed whether NC is coherent NC or non-coherent NC based is configured into the WTRU (e.g., UE) separately (for example via RRC configuration), while in FIG. 13, whether NC is coherent NC or non-coherent NC is indicated to the peer NC entity in NC PDU header. FIG. 13 also assumes there will be some exchange of control messages between NC peer entities.

[0372] FIG. 14 illustrates an example of non-coherent based NC PDU header (NC SDU concatenation based NC). FIG. 15 illustrates another example of non-coherent based NC PDU header (NC SDU concatenation based NC). In FIG. 14, it is assumed whether NC is coherent NC or non-coherent NC is configured into the WTRU (e.g., UE) separately (for example via RRC configuration), while in FIG. 15, whether NC is coherent NC or non-coherent NC is indicated to

the peer NC entity in NC PDU header. FIG. 15 also assumes there will be some exchange of control messages between NC peer entities.

[0373] Examples of NC encoding operation

[0374] FIG. 16 is an illustration (example) of NC SDU segmentation based encoding (no NC feedback assumed). FIG. 16 captures an example of a realization of WTRU (e.g., UE) processing of NC encoding, where the WTRU (e.g., UE) segments one or more (e.g., each) NC SDU to form a packet generation. It should be noted that the steps are structured in a particular order for illustration purposes, and could occur in different order.

[0375] Step 16.1: The WTRU (e.g., UE) may provide assistance information to the base station. The assistance information may include the WTRU (e.g., UE) NC device capability information.

[0376] Step 16.2: The WTRU (e.g., UE) may receive NC configuration parameters for NC processing control (at various level of NC processing control) as defined in this disclosure from the base station. See herein or in other sections, full configuration options.

[0377] Options for (semi-static, dynamic) configurations for input to NC processing may comprise option for configuration for bearer/NC PDU bearers as defined in this disclosure (as defined in previous sections or as described herein in other sections) to allow differentiated treatment and unequal error protection of NC PDUs at L3/network, L2/data link or L1/PHY layer.

[0378] Options for (semi-static, dynamic) configurations for input to NC processing may comprise options of configuration for Galois field & linear system related input.

[0379] Options of configuration for Galois field & linear system related input may comprise any parameters related to: (1) symbol/coding coefficient(s) size; (2) Galois field size; (3) generation type; (4) fixed block coding, (5) sliding window coding; (6) generation size configuration for fixed block coding; (7) generation size configuration for sliding window coding; (8) length of input packet configuration options; (9) generator matrix configuration options; (10) fixed code rate; (11) rateless; and (12) codebook configuration options.

[0380] Generation size configuration for fixed block coding may comprise parameters related to window size configuration options including range (min, max) values based for dynamic control of NC processing; default window size fixed value based; pre-NC PDU set based, timer-based, time-window based.

[0381] Generation size configuration for sliding window coding may comprise any parameters related to: (i) window size configuration options including range (min, max) values based for dynamic control of NC processing; Default window size fixed value based; pre-NC PDU set based, timer-based, time-window based; and (ii) Sliding step value configuration option (max/min and fix value based), time-based window sliding.

[0382] Length of input packet configuration options may comprise any parameters related to range (max, min), fixed value.

[0383] Generator matrix configuration options may comprise any parameters related to number of columns (range, fixed value); number of row (range, fixed value); symbol size (range, fixed value); generator matrix elements.

[0384] Generator matrix elements may comprise any parameters related to: random generation options and methods for generations; deterministic (explicit signaling of one or more (e.g., each) element and rules to associate elements to rows and columns, implicit approach with pointer to look-up matrix or sub-matrix of a matrix); and systematic code generator matrix options.

[0385] Fixed code rate may be defined for example, by range for dynamic control, fixed value, redundancy version or code rate index.

[0386] Rateless may comprise any parameters related to: rateless codes (sequence of code rate, sequence of redundancy version, options for representation of code rates), maximum number of NC iterations.

[0387] Codebook configuration options may comprise any parameters related to number of columns (range, fixed value); number of row (range, fixed value); symbol size (range, fixed value); and generator matrix elements.

[0388] Generator matrix elements may comprise any parameters related to random generation options and methods for generations; and deterministic (explicit signaling of one or more (e.g., each) element and rules to associate elements to rows and columns, implicit approach with pointer to look-up matrix or sub-matrix of a matrix).

[0389] Options of configuration (semi-static, dynamic) for network coding techniques/modes related inputs may comprise any of the following options: configuration for NC context control; configuration for activation/deactivation; configuration for conditions to start encoding; and configuration for conditions to start decoding.

[0390] Options for (semi-static, dynamic) configuration for output from NC Processing for an NC coding iteration may comprise parameters related to codeword configuration options (e.g., number of coded packets according to target code rate for the NC iteration).

[0391] Options for (semi-static, dynamic) configuration for output from NC Processing for an NC coding iteration may comprise parameters related to NC PDU header configuration options, (see paragraph "NC PDU header of NC PDU"):

[0392] NC PDU header configuration options may comprise parameters related to per packet explicit header information signaling a part of NC PDU. Support for coherent or non-coherent NC, codebook or non-codebook NC, Context ID, encoding vector option (explicit signaling of

coefficients, implicit signaling of coefficients, rules to match order of coefficient to generation packets), NC SDUs grouping NC processing, etc.)

[0393] NC PDU header configuration options may comprise parameters related to implicit header information derivation at WTRU (e.g., UE) based on (pre)configuration.

[0394] NC PDU header configuration options may comprise parameters related to configuration options for assignment of NC PDUs to NC PDU bearers (see paragraph describing the assignment of NC PDUs from same NC iteration to NC PDU bearer for transmission: (i) split of NC PDUs (equal split, rule based split, threshold based split; (ii) duplication of NC PDUs (full duplication, partial duplication, order of transmission of duplicated packets for one or more (e.g., each) NC PDU bearer); (iii) per NC PDU routing, per NC PDU set routing.

[0395] Step 16.3: The WTRU (e.g., UE) performs measurements to enable NC control processing decisions at the WTRU (e.g., UE), based on the NC related configurations received from the base station. The WTRU (e.g., UE) may also report the measurement results decision to the base station to enable NC related decisions. Example of such decisions may be about whether or not to perform NC, or about NC processing control e.g., adaptive NC, or assignment of NC PDUs to NC PDU bearers (as defined in this disclosure). Examples of measurements performed by the WTRU (e.g., UE) may include CSI (CQI, RI, PMI) measurements, RRM related measurements (e.g., RSRP/L1-RSRP), data volume/buffer status in support of QoS-aware NC processing control, power headroom in support of power-aware NC processing control.

[0396] Step 16.4 & Step 16.5: Data becomes available in the TX buffer for transmission. The WTRU (e.g., UE) determines the NC techniques to use for as example as a function of one or more NC Processing control options described as described in previous sections or as described herein in other sections of this disclosure. In this example, one of the NC Processing control options selected is NCD SDU segmentation based network coding.

[0397] Step 16.6 & Step 16.7: The WTRU (e.g., UE) may retrieve an NC SDU from its transmit buffer. The WTRU (e.g., UE) uses its determination from step 16.5 of NC SDU based NC segmentation to decide that a new NC context shall be instantiated, and instantiate a new NC context. Specifically, as described in previous sections or as described herein in other sections, the WTRU (e.g., UE) determines that the NC SDU doesn't belong to any existing NC generation. See previous sections or as described herein in other sections for details on NC context information. As part of the context instantiation, the WTRU (e.g., UE) assigns a context ID to the newly created context, see NC context control detail in previous sections, or as described herein in other sections. The WTRU (e.g., UE) creates a generator matrix and assign a generator matrix ID, or a NC generation sequence number to the generator matrix. The WTRU (e.g., UE) initializes the NC

iteration to 0. The WTRU (e.g., UE) also set the maximum allowed value of NC iteration for this NC context based according to the paragraph «NC Context control» in previous sections, or as described herein in other sections. The WTRU (e.g., UE) may also set the NC context timer.

[0398] Step 16.8: The WTRU (e.g., UE) determines the generation size to use for example as a function of one or more NC Processing control options described in previous sections or as described herein in other sections of this disclosure. The WTRU (e.g., UE) segments the NC SDU in as many NC SDU segments as the generation size. For example, the WTRU (e.g., UE) may determine the generation size, as a function of the configuration of the bearer associated with NC SDU, or as a function of both the bearer configuration and NC processing related measurements (see step 16.3).

[0399] Step 16.9: The WTRU (e.g., UE) determines the number of coded packets to be generated, for example according to one or more NC Processing control options described in previous sections, or as described herein in other sections of this disclosure (see for example the section describing the Galois field & linear system related input and specifically Code Rates subparagraph, and the section describing the output from NC Processing for one or more (e.g., each) NC iteration, for additional detail). For example, the WTRU (e.g., UE) may determine the number of coded packets to be generated for an NC iteration as a function of the configuration of the bearer associated with NC SDU, or as a function of both the bearer configuration and NC processing related measurements (see step 16.3).

[0400] Step 16.10: The WTRU (e.g., UE) determines encoding coefficient for one or more (e.g., each) packet to be generated, for example according to one or more NC Processing control options described in previous sections, or as described herein in other sections of this disclosure (see paragraph "Galois field & linear system related input", and specifically the NC processing control for generator matrix determination sub-paragraph. For example, the WTRU (e.g., UE) may determine the generator matrix to use as a function of the generator matrix control information received from the base station. For example, as captured in previous sections, or as described herein in other sections, the WTRU (e.g., UE) may generate the coding coefficients randomly based on for example configuration parameters from the network for random coefficient generation, such as generator matrix ID, random generation seed value, order in which the coding coefficients much be generated and used (for example matrix elements generation per row, in ascending order of column indexes or descending order of column indexes, or matrix elements generation per column, in ascending order of row indexes or descending order of row indexes.). In another example, the WTRU (e.g., UE) may determine the coding coefficients to use deterministically based on one or more of a look-up/(pre)configured generator matrix, the order in

which the coefficient much be selected and used from the look-up/(pre)configured generator matrix as described in the generator matrix determination sub-paragraph, of the "Galois field & linear system related input" paragraph previous sections, or as described herein in other sections. The WTRU (e.g., UE) uses the order of "generation and use" (random generation case), or order of "selection and use" (deterministic generator matrix case) indicated by the base station in support of coherent based NC operation, e.g., to ensure a row of a generator matrix in a WTRU (e.g., UE) points to the same row of the same generator matrix in the serving base station, or a column of a generator matrix in a WTRU (e.g., UE) points to the same column of the same generator matrix in the serving base station.

[0401] Step 16.11: The WTRU (e.g., UE) generates as many coded packets as the number of coded packets to be generated as determined in step 16.9, using the coding coefficients for one or more (e.g., each) coded packet to be generated as determined in step 16.10. At this step, the WTRU (e.g., UE) may also perform data volume calculation and report BSR to the base station.

[0402] Step 16.12: The WTRU (e.g., UE) creates and add an encoding vector to one or more (e.g., each) of the generated coded packets to form NC PDUs for this iteration of NC. As captured in paragraph «NC PDU header of NC PDU» of previous sections, or as described herein in other sections, the WTRU (e.g., UE) may construct the header to indicate options of NC used for e.g., coherent or non-coherent NC mode indication, codebook or non-codebook indication, segmentation based NC, concatenation based NC, hybrid segmentation or concatenation based NC. The WTRU (e.g., UE) orders the input NC SDU-segments in this NC context generation, to match the order of corresponding coefficient in the encoding vector. This allows the receiver to identify the position of an NC SDU segment in the SDU as the position of the corresponding coding coefficient in the encoding vector, in support of the NC SDU re-assembly (see detail in paragraph «NC PDU header of NC PDU» as described herein in other sections.

[0403] Step 16.13: The WTRU (e.g., UE) determines NC PDU bearers configured and activated for transmission that can be used for the NC PDU generated in this NC iteration, for example according to one or more NC Processing control options described in previous sections, or as described herein in other sections in terms of NC PDU bearer configuration and activation/deactivation. The assigns/submit the NC PDUs to activated NC PDU bearers for transmission. See detail of NC PDU bearer assignment according to the paragraph describing the assignment of NC PDUs from same NC iteration to NC PDU bearer for transmission, as captured in previous sections, or as described herein in other sections. The lower layers transmit the NC PDU according to the NC PDU bearer configuration as defined and described in previous sections, or as described herein in other sections. For example, if NC is implemented above MC, the WTRU

(e.g., UE) may enforce LCP restrictions at the MAC layer using the PCP bearer configuration and specifically (logical channel configuration restriction as described in previous sections or as described herein in other sections.

[0404] Step 16.14, step 16.15, and step 16.16: The WTRU (e.g., UE) determines if the NC context should be released. For example, if the NC is non-adaptive NC and non-feedback based NC, the WTRU (e.g., UE) may release the NC context. For the case of adaptive NC, or feedback based NC, the WTRU (e.g., UE) may release the NC context if the NC iteration count reaches the maximum NC iteration count, or the timer for NC context release expires, see step 16.6 & 16.7 above, or paragraph "NC Context control" in previous sections, or as described herein in other sections). If the WTRU (e.g., UE) determines that the context should not be release, the WTRU (e.g., UE) update the context with necessary context information as described in previous sections or as described herein in other sections.

[0405] FIG. 17 is an Illustration (example) of NC SDU segmentation based encoding (NC Feedback assumed). FIG. 17 captures an example of a realization of WTRU (e.g., UE) processing of NC encoding, where the WTRU (e.g., UE) segments one or more (e.g., each) NC SDU to form a packet generation with the option to perform rateless coding based on feedback from the receiver. Step 17.1 is a summary of one or more (e.g., all the) steps described in FIG. 16. It should be noted that the steps are structured in a particular order for illustration purposes, and could occur in different order. The WTRU may receive feedback from the decoder (step 17.2). The WTRU may identify NC context for this feedback (step 17.3). If the WTRU determine to generate additional coded packet (step 17.4), the WTRU may determine number of coded packets to be generated (step 17.5). The WTRU may determine encoding coefficient for each coded packet to be generated (step 17.6). The WTRU may generate coded packet(s) (step 17.7), and/or add header to each of the generated coded packets to form NC PDU(s) (step 17.8). The WTRU may assign NC PDUs to NC PDU Bearers and transmit the NC PDU(s) (step 17.9). The WTRU may determine whether it releases NC Context for NC SDU Packet i (P_i) (step 17.10). If the WTRU determine to release NC Context for NC SDU P_i , it may release NC Context for NC SDU P_i (step 17.12). If the WTRU determine to not release NC Context for NC SDU P_i , it may update the NC Context for NC SDU P_i (step 17.11).

[0406] FIG. 18 is an illustration (example) of NC SDU concatenation based encoding (no NC feedback assumed), FIG. 18 captures an example of a realization of WTRU (e.g., UE) processing of NC encoding, where the WTRU (e.g., UE) concatenate two or more NC SDU to form a packet generation for this NC, e.g., the input packets to the NC are whole NC SDUs, and not segmented NC SDUs. One key embodiment that may separate concatenation based example realization, from

segmentation based example realization described above is the formation of the NC generation e.g., the NC generation, and the implication for the WTRU (e.g., UE) to check condition to start NC encoding (step 18.10 of FIG. 18). As described in the paragraph "conditions to start encoding" in previous sections, or as described herein in other sections, the WTRU (e.g., UE) may determine whether to concatenate packets to form generation size using configuration received from the base station. The configuration may be at various level of NC Processing granularity. The WTRU (e.g., UE) (e.g., then) (e.g., must) may decide when to start encoding.

[0407] Steps 18.1 to 18.5 may correspond to steps 16.1 to 16.5 of FIG. 16.

[0408] The WTRU may determine a max number of NC SDU to be jointly encoded (step 18.6).

[0409] The WTRU (e.g., UE) may retrieve one or more NC SDUs from its transmit buffer (step 18.7).

[0410] The WTRU may determine whether a NC context is already instantiated for these NC SDUs to be jointly encoded (step 18.8). If no NC context is instantiated, the WTRU may instantiate a NC context (step 18.9).

[0411] The WTRU may determine condition to start NC encoding (step 18.10).

[0412] The WTRU may determine number of coded packets to be generated (step 18.11). The WTRU may determine encoding coefficient for each coded packet to be generated (step 18.12). The WTRU may generate coded packet(s) (step 18.13), and/or add header to each of the generated coded packets to form NC PDU(s) (step 18.14). The WTRU may assign NC PDUs to NC PDU Bearers and transmit the NC PDU(s) (step 18.15). The WTRU may determine whether it releases NC Context for the NC SDUs being jointly encoded (step 18.16). If the WTRU determine to release NC Context for the NC SDUs jointly encoded, it may release NC Context for the NC SDUs jointly encoded (step 18.18). If the WTRU determine to not release NC Context for the NC SDUs jointly encoded, it may update the NC Context for the NC SDUs jointly encoded (step 18.17).

[0413] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, and WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding as soon as an NC SDU within the generation (or encoding window) for this NC context becomes available at the WTRU (e.g., UE) TX buffer;

[0414] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding as soon as two or more NC SDU within the generation become available at the TX buffer;

[0415] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, and the WTRU (e.g., UE) configuration for condition to

start encoding indicates as soon as a threshold based for e.g., absolute value, or percentage of the number of NC SDUs of the generation becomes available at the WTRU (e.g., UE) TX buffer;

[0416] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: the WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding (e.g., only) when one or more (e.g., all the) NC SDUs of the generation become available.

[0417] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding upon a timer expiry. Note: The value of this timer may be configured into the WTRU (e.g., UE), for example based on the delay budget associated with the QoS/bearer configuration for this traffic flow, or the delay budget of the most time sensitive NC SDUs within this NC generation.

[0418] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding, as soon as an NC SDU within the NC SDU set becomes available.

[0419] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding as soon as two or more NC SDU within the NC SDU set become available at the TX buffer;

[0420] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates as soon as a threshold based for e.g., absolute value, or percentage of the number of NC SDUs of the NC SDU set becomes available at the WTRU (e.g., UE) TX buffer;

[0421] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding (e.g., only) when one or more (e.g., all the) NC SDUs of the NC SDU set become available.

[0422] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding, as soon as the packet/NC SDU of the highest importance within the SDU set becomes available.

[0423] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding, as soon as a packet/NC SDU having an importance above a threshold becomes available.

[0424] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding, as soon as one or more (e.g., all the) packet/NC SDUs having an importance above a threshold becomes available.

[0425] The WTRU (e.g., UE) may determine (e.g., when) to start encoding in the case where: NC SDU is available in the TX buffer, the WTRU (e.g., UE) is configured to perform NC encoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start encoding indicates to start NC encoding upon a timer expiry. Note: The value of this timer may be configured into the WTRU (e.g., UE), for example in relation with the pre-NC PDU set delay budget.

[0426] FIG. 19 is an illustration (example) of NC SDU concatenation based encoding (NC feedback assumed). FIG 19 captures an example of a realization of WTRU (e.g., UE) processing of NC encoding with rateless coding option, where the WTRU (e.g., UE) concatenate two or more NC SDU to form a packet generation for this NC, e.g., the input packets to the NC are whole NC SDUs, and not segmented NC SDUs.

[0427] Step 19.1 is a summary of one or more (e.g., all the) steps described in FIG. 16. It should be noted that the steps are structured in a particular order for illustration purposes, and could occur in different order. The WTRU may receive feedback from the decoder (step 19.2). The WTRU may identify NC context for this feedback (step 19.3).

[0428] The WTRU may determine a max number of NC SDU to be jointly encoded (step 19.4).

[0429] The WTRU (e.g., UE) may retrieve one or more NC SDUs from its transmit buffer (step 19.5).

[0430] The WTRU may determine whether a NC context is already instantiated for these NC SDUs to be jointly encoded (step 19.6). If no NC context is instantiated, the WTRU may instantiate a NC context (step 19.7).

[0431] The WTRU may determine a number of coded packets to be generated (step 19.8). The WTRU may determine encoding coefficient for each coded packet to be generated (step 19.9). The WTRU may generate coded packet(s) (step 19.10), and/or add header to each of the generated coded packets to form NC PDU(s) (step 19.11). The WTRU may assign NC PDUs to NC PDU Bearers and transmit the NC PDU(s) (step 19.12). The WTRU may determine whether it releases NC Context for the NC SDUs being jointly encoded (step 19.13). If the WTRU determine to release NC Context for the NC SDUs jointly encoded, it may release NC Context for the NC SDUs jointly encoded (step 19.15). If the WTRU determine to not release NC Context for the NC SDUs jointly encoded, it may update the NC Context for the NC SDUs jointly encoded (step 19.14).

[0432] Examples of NC decoding operation

[0433] FIG. 20 is an illustration (example) of NC SDU segmentation based decoding. FIG. 20 captures an example of a realization of WTRU (e.g., UE) processing of NC decoding, with segmentation based NC e.g., the packet generation that contributes to the received NC PDUs may include (e.g., consists of) NC SDU segments.

[0434] The WTRU (e.g., UE) may provide assistance information to the base station. The assistance information may include the WTRU (e.g., UE) NC device capability information (step 20.1).

[0435] The WTRU (e.g., UE) may receive NC configuration parameters for NC processing control (at various level of NC processing control) as defined in this disclosure from the base station (step 20.2). See previous sections or as described herein in other sections for full configuration options.

[0436] Options for (semi-static, dynamic) configurations for input to NC processing may comprise option for configuration for bearer/NC PDU bearers as defined in this disclosure (as defined in previous sections or as described herein in other sections) to allow differentiated treatment and unequal error protection of NC PDUs at L3/network, L2/data link or L1/PHY layer.

[0437] Options for (semi-static, dynamic) configurations for input to NC processing may comprise options of configuration for Galois field & linear system related input.

[0438] Options of configuration for Galois field & linear system related input may comprise any parameters related to: (1) symbol/coding coefficient(s) size; (2) Galois field size; (3) generation type; (4) fixed block coding, (5) sliding window coding; (6) generation size configuration for fixed block coding; (7) generation size configuration for sliding window coding; (8) length of input

packet configuration options; (9) generator matrix configuration options; (10) fixed code rate; (11) rateless; and (12) codebook configuration options.

[0439] Generation size configuration for fixed block coding may comprise parameters related to window size configuration options including range (min, max) values based for dynamic control of NC processing; default window size fixed value based; pre-NC PDU set based, timer-based, time-window based.

[0440] Generation size configuration for sliding window coding may comprise any parameters related to: (i) window size configuration options including range (min, max) values based for dynamic control of NC processing; Default window size fixed value based; pre-NC PDU set based, timer-based, time-window based; and (ii) Sliding step value configuration option (max/min and fix value based), time-based window sliding.

[0441] Length of input packet configuration options may comprise any parameters related to range (max, min), fixed value.

[0442] Generator matrix configuration options may comprise any parameters related to number of columns (range, fixed value); number of row (range, fixed value); symbol size (range, fixed value); generator matrix elements.

[0443] Generator matrix elements may comprise any parameters related to: random generation options and methods for generations; deterministic (explicit signaling of one or more (e.g., each) element and rules to associate elements to rows and columns, implicit approach with pointer to look-up matrix or sub-matrix of a matrix); and systematic code generator matrix options.

[0444] Fixed code rate may be defined for example, by range for dynamic control, fixed value, redundancy version or code rate index.

[0445] Rateless may comprise any parameters related to: rateless codes (sequence of code rate, sequence of redundancy version, options for representation of code rates), maximum number of NC iterations.

[0446] Codebook configuration options may comprise any parameters related to number of columns (range, fixed value); number of row (range, fixed value); symbol size (range, fixed value); and generator matrix elements.

[0447] Generator matrix elements may comprise any parameters related to random generation options and methods for generations; and deterministic (explicit signaling of one or more (e.g., each) element and rules to associate elements to rows and columns, implicit approach with pointer to look-up matrix or sub-matrix of a matrix).

[0448] Options of configuration (semi-static, dynamic) for network coding techniques/modes related inputs may comprise any of the following options: configuration for NC context control;

configuration for activation/deactivation; configuration for conditions to start encoding; and configuration for conditions to start decoding.

[0449] Options for (semi-static, dynamic) configuration for output from NC Processing for an NC coding iteration may comprise parameters related to codeword configuration options (e.g., number of coded packets according to target code rate for the NC iteration).

[0450] Options for (semi-static, dynamic) configuration for output from NC Processing for an NC coding iteration may comprise parameters related to NC PDU header configuration options, (see paragraph "NC PDU header of NC PDU"):

[0451] NC PDU header configuration options may comprise parameters related to per packet explicit header information signaling a part of NC PDU. Support for coherent or non-coherent NC, codebook or non-codebook NC, Context ID, encoding vector option (explicit signaling of coefficients, implicit signaling of coefficients, rules to match order of coefficient to generation packets), NC SDUs grouping NC processing, etc.)

[0452] NC PDU header configuration options may comprise parameters related to implicit header information derivation at WTRU (e.g., UE) based on (pre)configuration.

[0453] NC PDU header configuration options may comprise parameters related to configuration options for assignment of NC PDUs to NC PDU bearers (see paragraph describing the assignment of NC PDUs from same NC iteration to NC PDU bearer for transmission: (i) split of NC PDUs (equal split, rule based split, threshold based split; (ii) duplication of NC PDUs (full duplication, partial duplication, order of transmission of duplicated packets for one or more (e.g., each) NC PDU bearer); (iii) per NC PDU routing, per NC PDU set routing.

[0454] NC PDUs may become available in the RX buffer. The WTRU (e.g., UE) may retrieve one or more NC PDUs from the RX buffer (step 20.3 and step 20.4).

[0455] The WTRU (e.g., UE) may determine if there is already an existing context for the retrieved NC PDU (step 20.5). For example, the WTRU (e.g., UE), if the NC context ID in the NC PDU header is same as one of the NC context IDs of the existing NC contexts at the WTRU (e.g., UE), the WTRU (e.g., UE) concludes there is already an existing context for the retrieved NC PDU. If the NC context ID in the PCP PDU header doesn't match any of the NC context IDs of the existing NC contexts in the WTRU (e.g., UE), the WTRU (e.g., UE) concludes the NC context for the retrieved NC PDU is a new NC context. In another alternative, NC contexts may be associated via configuration (see «NC PDU header of NC PDU» paragraph in previous sections, or as described herein in other sections) to an NC PDU bearer (for e.g., RLC bearer). In this alternative, the WTRU (e.g., UE) determines there is already a NC context for the retrieved NC PDU, if there is already at the WTRU (e.g., UE) a NC context for the NC PDU bearer used to

receive the NC PDU. Similarly, the WTRU (e.g., UE) may determine the NC context of the retrieved NC PDU is a new NC context if there is no existing NC context at the WTRU (e.g., UE) for the NC PDU bearer used to receive the NC PDU. See previous sections or as described herein in other sections for details on NC context information.

[0456] If the context of the retrieved NC PDU (at step 20.4) is a new context, the WTRU (e.g., UE) may instantiate a new NC context (step 20.6). As part of the context instantiation, the WTRU (e.g., UE) assigns a context ID to the newly created context, see NC context control detail previous sections, or as described herein in other sections (paragraph NC Context control). The WTRU (e.g., UE) may create a generator matrix and assign a generator matrix ID, or a NC generation sequence number to the generator matrix. The WTRU (e.g., UE) may initialize the NC iteration to 0. The WTRU (e.g., UE) may set the maximum allowed value of NC iteration for this NC context based according to the paragraph «NC Context control» in previous sections, or as described herein in other sections. The WTRU (e.g., UE) may set the NC context timer. The WTRU (e.g., UE) may record the encoding coefficients of the received NC PDU, in the same order as indicated by the encoder (regardless of whether the coefficients are signaled explicitly e.g., non-coherent NC case, or the coefficient are signaled implicitly i.e., coherent NC case, see detail in «NC PDU header of NC PDU» of previous sections, or as described herein in other sections.

[0457] If the context of the retrieved NC PDU (at step 20.4) is an existing context, the WTRU (e.g., UE) may verify if the NC SDU associated with this context is already successfully decoded (step 20.7). If yes, the decoding process ends. For example, the WTRU (e.g., UE) may temporarily keep records of NC context for which NC SDU has been successfully recovered, but context ID still stored at the WTRU (e.g., UE), in order to handle scenarios where an NC SDU has been recovered but there are still associated NC PDUs in flight. Such NC context records may (e.g., only) include context ID and an indication or flag e.g., 1 bit that the WTRU (e.g., UE) set to track if the associated NC SDU has been successfully recovered (e.g., flag set to 1) or not recovered (e.g., flag set to 0). The WTRU (e.g., UE) may use this successfully recovered NC SDU NC tracking record to determine if the NC SDU associated with a retrieved NC PDU from the WTRU (e.g., UE) RX buffer, is already successfully decoded or not successfully decoded.

[0458] If the retrieved NC PDU at step 20.4 is not associated with an NC SDU that is already recovered, the WTRU (e.g., UE) may update the corresponding NC context with the necessary information (for example including the generator matrix) as described in previous sections or as described herein in other sections (step 20.8). The WTRU (e.g., UE) may record the encoding coefficients of the received NC PDU, in the same order as indicated by the encoder (regardless of whether the coefficients are signaled explicitly e.g., non-coherent NC case, or the coefficient are

signaled implicitly i.e., coherent NC case, see detail in «NC PDU header of NC PDU» of previous sections, or as described herein in other sections.

[0459] The WTRU (e.g., UE) may determine the NC techniques to use for as example according to the one or more NC Processing control options described in previous sections, or as described herein in other sections of this disclosure (step 20.9). In this example, one of the NC Processing control options identified by the decoding WTRU (e.g., UE) is NC SDU segmentation based network coding.

[0460] The WTRU (e.g., UE) may determine if conditions are fulfilled to start decoding (step 20.10). The WTRU (e.g., UE) may make such decision for example as function of NC processing control functions described in the paragraph "Conditions to start decoding" in previous sections, or as described herein in other sections.

[0461] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as an NC PDU for this NC context becomes available at the WTRU (e.g., UE) RX buffer;

[0462] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as two or more NC PDU for this NC context become available at the RX buffer;

[0463] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates as soon as a threshold based for e.g., absolute value, or percentage of the number of NC PDUs for this context becomes available at the WTRU (e.g., UE) RX buffer;

[0464] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding (e.g., only) when one or more (e.g., all the) NC PDUs corresponding to the target coding rate for this NC iteration of this NC context become available at the RX buffer.

[0465] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as one or more packet of the highest importance within the NC context for the corresponding NC SDU become available at the RX buffer. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority

of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections or as described herein in other sections for additional details on NC PDU bearer configuration.

[0466] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as one or more packet with importance above a threshold within the NC context for the corresponding NC SDU become available at the RX buffer. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections or as described herein in other sections for additional details on NC PDU bearer configuration.

[0467] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding upon a timer expiry. Note: The value of this timer may be configured into the WTRU (e.g., UE), for example based on the delay budget associated with the QoS/bearer configuration for this traffic flow, or the delay budget of the most time sensitive NC SDUs within this NC generation.

[0468] The WTRU (e.g., UE) may perform decoding, according to the NC options used by the encoder for NC context and NC iteration (step 20.11).

[0469] The WTRU (e.g., UE) may verify if one or more (e.g., all) NC SDU segments have been successfully recovered, e.g., if the decoding process is successful (step 20.12). The WTRU (e.g., UE) may determine that one or more (e.g., all) NC SDU segments have been successfully recovered if the decoding process yields as many as NC SDU segments as the generation size. Alternatively, the WTRU (e.g., UE) may determine that the number of NC SDU segments successfully recovered is less than the generation size, in which case, the WTRU (e.g., UE) concludes that the decoding operation is unsuccessful.

[0470] If the WTRU (e.g., UE) determines that the decoding is unsuccessful, the WTRU (e.g., UE) may generate feedback to inform the encoding entity (step 20.13). The WTRU (e.g., UE) may check if condition to send feedback is fulfilled with one or more of the following conditions: a) the WTRU (e.g., UE) determines from step 9 that the NC is feedback based NC; b) the NC is adaptive NC; c) The NC is rateless based NC. The feedback may include one or more of the following: a) number of missing NC PDU e.g., additional number of PDU required to achieve full rank for the generator matrix; b) NC techniques to use next for NC PDU transmission; c) NC PDU

bearer or bearer configuration parameter to used (e.g., grant type e.g., CG, DG, or grant configuration); d) etc.

[0471] The WTRU (e.g., UE) may generate a NC feedback control PDU and submit to lower layers for transmission (step 20.14).

[0472] For example, from step 20.11, the WTRU (e.g., UE) may have the NC SDU segments in an order that matches the order of the columns of the coding coefficients in the generator matrix (step 20.15). The WTRU (e.g., UE) may use that order to re-assemble the NC SDU segments into the NC SDU retrieved from the NC RX buffer. The WTRU (e.g., UE) may also update its context with mapping of NC context ID to successful decoding flag e.g., sets the flag to 1 and associate it with this NC context ID (see step 20.7)

[0473] The WTRU (e.g., UE) may submit the NC SDU to upper layers (step 20.16).

[0474] The WTRU may check if the NC context should be release. For example, if the NC is non-adaptive NC and non-feedback based NC, the WTRU (e.g., UE) may release the NC context. For the case of adaptive NC, or feedback based NC, the WTRU (e.g., UE) may release the NC context if the NC iteration count reaches the maximum NC iteration count, or the timer for NC context release expires, see step 20.6 & 20.7 above, or paragraph «NC Context control» in previous sections, or as described herein in other sections). If the WTRU (e.g., UE) determines that the context should not be release, the WTRU (e.g., UE) keep the context (steps 20.17, 20.18, and 20.19).

[0475] FIG. 21 is an Illustration (example) of NC SDU concatenation based decoding. FIG. 21 captures an example of a realization of WTRU (e.g., UE) processing of NC decoding for NC concatenation based encoding. In step 21.10, the WTRU (e.g., UE) may make decision to start decoding for example as function of NC processing control functions described in the paragraph "Conditions to start decoding" in previous sections, or as described herein in other sections.

[0476] The WTRU (e.g., UE) may provide assistance information to the base station. The assistance information may include the WTRU (e.g., UE) NC device capability information (step 21.1).

[0477] The WTRU (e.g., UE) may receive NC configuration parameters for NC processing control (at various level of NC processing control) as defined in this disclosure from the base station (step 21.2). See previous sections or as described herein in other sections for full configuration options.

[0478] NC PDUs may become available in the RX buffer. The WTRU (e.g., UE) may retrieve one or more NC PDUs from the RX buffer (step 21.3 and step 21.4).

[0479] The WTRU (e.g., UE) may determine if there is already an existing context for the retrieved NC PDU (step 21.5). For example, the WTRU (e.g., UE), if the NC context ID in the NC PDU header is same as one of the NC context IDs of the existing NC contexts at the WTRU (e.g., UE), the WTRU (e.g., UE) concludes there is already an existing context for the retrieved NC PDU. If the NC context ID in the PCP PDU header doesn't match any of the NC context IDs of the existing NC contexts in the WTRU (e.g., UE), the WTRU (e.g., UE) concludes the NC context for the retrieved NC PDU is a new NC context. In another alternative, NC contexts may be associated via configuration (see «NC PDU header of NC PDU» paragraph in previous sections, or as described herein in other sections) to an NC PDU bearer (for e.g., RLC bearer). In this alternative, the WTRU (e.g., UE) determines there is already a NC context for the retrieved NC PDU, if there is already at the WTRU (e.g., UE) a NC context for the NC PDU bearer used to receive the NC PDU. Similarly, the WTRU (e.g., UE) may determine the NC context of the retrieved NC PDU is a new NC context if there is no existing NC context at the WTRU (e.g., UE) for the NC PDU bearer used to receive the NC PDU. See previous sections or as described herein in other sections for details on NC context information.

[0480] If the context of the retrieved NC PDU (at step 21.4) is a new context, the WTRU (e.g., UE) may instantiate a new NC context (step 21.7). As part of the context instantiation, the WTRU (e.g., UE) may assign a context ID to the newly created context, see NC context control detail previous sections, or as described herein in other sections (paragraph NC Context control). The WTRU (e.g., UE) may create a generator matrix and assign a generator matrix ID, or a NC generation sequence number to the generator matrix. The WTRU (e.g., UE) may initialize the NC iteration to 0. The WTRU (e.g., UE) may set the maximum allowed value of NC iteration for this NC context based according to the paragraph «NC Context control» in previous sections, or as described herein in other sections. The WTRU (e.g., UE) may set the NC context timer. The WTRU (e.g., UE) may record the encoding coefficients of the received NC PDU, in the same order as indicated by the encoder (regardless of whether the coefficients are signaled explicitly e.g., non-coherent NC case, or the coefficient are signaled implicitly i.e., coherent NC case, see detail in «NC PDU header of NC PDU» of previous sections, or as described herein in other sections.

[0481] If the context of the retrieved NC PDU (at step 21.4) is an existing context, the WTRU (e.g., UE) may verify if the NC SDU associated with this context is already successfully decoded (step 21.6). If yes, the decoding process ends. For example, the WTRU (e.g., UE) may temporarily keep records of NC context for which NC SDU has been successfully recovered, but context ID still stored at the WTRU (e.g., UE), in order to handle scenarios where an NC SDU has been recovered but there are still associated NC PDUs in flight. Such NC context records may (e.g.,

only) include context ID and an indication or flag e.g., 1 bit that the WTRU (e.g., UE) set to track if the associated NC SDU has been successfully recovered (e.g., flag set to 1) or not recovered (e.g., flag set to 0). The WTRU (e.g., UE) may use this successfully recovered NC SDU NC tracking record to determine if the NC SDU associated with a retrieved NC PDU from the WTRU (e.g., UE) RX buffer, is already successfully decoded or not successfully decoded.

[0482] If the retrieved NC PDU at step 21.4 is not associated with an NC SDU that is already recovered, the WTRU (e.g., UE) may update the corresponding NC context with the necessary information (for example including the generator matrix) as described in previous sections or as described herein in other sections (step 21.8). The WTRU (e.g., UE) may record the encoding coefficients of the received NC PDU, in the same order as indicated by the encoder (regardless of whether the coefficients are signaled explicitly e.g., non-coherent NC case, or the coefficient are signaled implicitly i.e., coherent NC case, see detail in «NC PDU header of NC PDU» of previous sections, or as described herein in other sections.

[0483] The WTRU (e.g., UE) may determine the NC techniques to use for as example according to the one or more NC Processing control options described in previous sections, or as described herein in other sections of this disclosure (step 21.9). In this example, one of the NC Processing control options identified by the decoding WTRU (e.g., UE) is NC SDU segmentation based network coding.

[0484] The WTRU (e.g., UE) may determine if conditions are fulfilled to start decoding (step 21.10). The WTRU (e.g., UE) may make such decision for example as function of NC processing control functions described in the paragraph "Conditions to start decoding" in previous sections, or as described herein in other sections.

[0485] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as an NC PDU for this NC context becomes available at the WTRU (e.g., UE) RX buffer;

[0486] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as two or more NC PDU for this NC context become available at the RX buffer;

[0487] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates as soon as a threshold based for e.g., absolute value, or percentage of the number of NC PDUs for this context becomes available at the WTRU (e.g., UE) RX buffer;

[0488] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding (e.g., only) when one or more (e.g., all the) NC PDUs corresponding to the target coding rate for this NC iteration of this NC context become available at the RX buffer.

[0489] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as one or more packet of the highest importance within the NC context for the corresponding NC SDU become available at the RX buffer. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections or as described herein in other sections for additional details on NC PDU bearer configuration.

[0490] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC encoding as soon as one or more packet with importance above a threshold within the NC context for the corresponding NC SDU become available at the RX buffer. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections, for additional details on NC PDU bearer configuration.

[0491] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding upon a timer expiry. Note: The value of this timer may be configured into the WTRU (e.g., UE), for example based on the delay budget associated with the QoS/bearer configuration for this traffic flow, or the delay budget of the most time sensitive NC SDUs within this NC generation.

[0492] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding, as soon as an NC PDU associated with an NC context for the corresponding NC SDU set becomes available. The decoding WTRU (e.g., UE) may identify an NC SDU set based of an association between PDU set and Context ID (or

generation ID) at the transmitter. The WTRU (e.g., UE) learns about such association dynamically on per NC PDU basis based on NC context ID included in the received NC PDU header. Alternatively, the WTRU (e.g., UE) may learn about such association semi-statically based on configuration received by the WTRU (e.g., UE) for example where PDU set configuration may be associated with specific NC PDU bearer. See paragraph «NC PDU header of NC PDU» in previous sections, or as described herein in other sections for additional details.

[0493] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding, as soon as two or more NC PDUs associated with the NC context for the corresponding NC SDU set become available. The decoding WTRU (e.g., UE) may identify an NC SDU set based on an association between PDU set and Context ID (or generation ID) at the transmitter. The WTRU (e.g., UE) learns about such association dynamically on per NC PDU basis based on NC context ID included in the received NC PDU header. Alternatively, the WTRU (e.g., UE) may learn about such association semi-statically based on configuration received by the WTRU (e.g., UE) for example where PDU set configuration may be associated with specific NC PDU bearer. See paragraph «NC PDU header of NC PDU» in previous sections, or as described herein in other sections for additional details.

[0494] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (i.e. NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding, as soon as a threshold based for e.g. absolute value, or percentage of the number of NC PDUs associated with the NC context for the corresponding NC SDU set become available. The decoding WTRU (e.g., UE) may identify an NC SDU set based on an association between PDU set and Context ID (or generation ID) at the transmitter. The WTRU (e.g., UE) learns about such association dynamically on per NC PDU basis based on NC context ID included in the received NC PDU header. Alternatively, the WTRU (e.g., UE) may learn about such association semi-statically based on configuration received by the WTRU (e.g., UE) for example where PDU set configuration may be associated with specific NC PDU bearer. See paragraph «NC PDU header of NC PDU» in previous sections, or as described herein in other sections for additional details.

[0495] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for

condition to start decoding indicates to start NC decoding (e.g., only) when one or more (e.g., all the) NC PDUs associated with the NC context for the corresponding NC SDU set become available. The decoding WTRU (e.g., UE) may identify an NC SDU set based of an association between PDU set and Context ID (or generation ID) at the transmitter. The WTRU (e.g., UE) learns about such association dynamically on per NC PDU basis based on NC context ID included in the received NC PDU header. Alternatively, the WTRU (e.g., UE) mean learn about such association semi-statically based on configuration received by the WTRU (e.g., UE) for example where PDU set configuration maybe associated with specific NC PDU bearer. See paragraph «NC PDU header of NC PDU» in previous sections, or as described herein in other sections for additional details.

[0496] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding as soon as the packet/NC PDU of the highest importance within the NC context for the corresponding NC SDU set become available. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections or as described herein in other sections for additional details on NC PDU bearer configuration.

[0497] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding as soon as a packet/NC PDUs having an importance above a threshold within the NC context for the corresponding NC SDU set become available. The decoding WTRU (e.g., UE) may identify the importance of an NC PDU within an NC context or iteration of an NC context based on for example the NC PDU bearer (example priority of the logical channel, priority of the grant, grant type, etc.) used for the reception of the NC PDU. See previous sections or as described herein in other sections for additional details on NC PDU bearer configuration.

[0498] The WTRU (e.g., UE) may determine (e.g., when) to start decoding in the case where: NC PDU is available in the RX buffer, the WTRU (e.g., UE) is configured to perform NC decoding on per pre-NC PDU set (e.g., NC SDU set) basis, and the WTRU (e.g., UE) configuration for condition to start decoding indicates to start NC decoding upon a timer expiry. Note: The value of

this timer may be configured into the WTRU (e.g., UE), for example in relation with the pre-NC PDU set delay budget.

[0499] The WTRU (e.g., UE) may perform decoding, according to the NC options used by the encoder for NC context and NC iteration (step 21.11).

[0500] The WTRU (e.g., UE) may verify if one or more (e.g., all) NC SDU segments have been successfully recovered, e.g., if the decoding process is successful (step 21.12). The WTRU (e.g., UE) may determine that one or more (e.g., all) NC SDU segments have been successfully recovered if the decoding process yields as many as NC SDU segments as the generation size. Alternatively, the WTRU (e.g., UE) may determine that the number of NC SDU segments successfully recovered is less than the generation size, in which case, the WTRU (e.g., UE) concludes that the decoding operation is unsuccessful.

[0501] If the WTRU (e.g., UE) determines that the decoding is unsuccessful, the WTRU (e.g., UE) may generate feedback to inform the encoding entity (step 21.13). The WTRU (e.g., UE) may check if condition to send feedback is fulfilled, for example, with one or more of the following conditions: a) the WTRU (e.g., UE) determines from step 21.9 that the NC is feedback based NC; b) the NC is adaptive NC; c) The NC is rateless based NC. The feedback may include one or more of the following: a) number of missing NC PDU e.g., additional number of PDU required to achieve full rank for the generator matrix; b) NC techniques to use next for NC PDU transmission; c) NC PDU bearer or bearer configuration parameter to used (e.g., grant type e.g., CG, DG, or grant configuration); d) etc.

[0502] The WTRU (e.g., UE) may generate a NC feedback control PDU and/or submit to lower layers for transmission (step 21.15).

[0503] If the WTRU (e.g., UE) determines that the decoding is unsuccessful, the WTRU (e.g., UE) may submit the NC SDU to upper layers (step 21.14).

[0504] The WTRU (e.g., UE) may check if condition to send feedback is fulfilled (step 21.16), for example, with one or more of the following conditions: a) the WTRU (e.g., UE) determines from step 21.9 that the NC is feedback based NC; b) the NC is adaptive NC; c) The NC is rateless based NC. The feedback may include one or more of the following: a) number of missing NC PDU e.g., additional number of PDU required to achieve full rank for the generator matrix; b) NC techniques to use next for NC PDU transmission; c) NC PDU bearer or bearer configuration parameter to used (e.g., grant type e.g., CG, DG, or grant configuration); d) etc.

[0505] The WTRU (e.g., UE) may generate a NC feedback control PDU and/or submit to lower layers for transmission (step 21.17).

[0506] The WTRU may check if the NC context should be release. For example, if the NC is non-adaptive NC and non-feedback based NC, the WTRU (e.g., UE) may release the NC context. For the case of adaptive NC, or feedback based NC, the WTRU (e.g., UE) may release the NC context if the NC iteration count reaches the maximum NC iteration count, or the timer for NC context release expires, see for example paragraph «NC Context control» in previous sections, or as described herein in other sections). If the WTRU (e.g., UE) determines that the context should not be release, the WTRU (e.g., UE) may determine if the context should be updated, and updated it if this determination is positive (steps 21.18, 21.19, 21.20 and 21.20).

[0507] FIG. 22 is a flowchart illustrating a representative method 2200 implemented by a WTRU. Referring to FIG. 22, the representative method 2200 may include, at block 2210, obtaining a first PDU processed by NC coding and a second PDU processed by NC coding. At block 2220, the representative method 2200 may include, determining that the first PDU and the second PDU are associated to a NC PDU set on condition that the first PDU and the second PDU are generated from network encoding of a same data block (e.g., SDU). At block 2230, the representative method 2200 may include, associating to the first PDU and the second PDU, information comprising an indication of the PDU set. At block 2240, the representative method 2200 may include assigning the first PDU and the second PDU to at least one NC PDU bearer. At block 2250, the representative method 2200 may include, transmitting the first PDU and the second PDU via the at least one NC PDU bearer.

[0508] In certain representative embodiments, the indication of the NC PDU set may comprise any of: (1) an identifier or sequence number of NC PDU set the PDU belongs to, (2) a first identifier or sequence number of the PDU within a NC PDU set, wherein at most one PDU may be associated to the identifier, and (3) a second identifier associated to one or more (e.g., each) PDU, wherein more than one PDU may be associated to the identifier.

[0509] In certain representative embodiments, the first PDU and the second PDU may be assigned to the at least one NC PDU bearer on per-NC PDU set basis.

[0510] In certain representative embodiments, the first PDU and the second PDU may be assigned to the at least one NC PDU bearer on per-NC PDU basis.

[0511] In certain representative embodiments, determining that the first PDU and the second PDU are associated to a PDU set may be based on any of: a configuration received, from L3, L2 signaling and/or configuration received from a serving base station, a peer receive node or a remote node, or based on predefined rules.

[0512] In certain representative embodiments, determining that the first PDU and the second PDU are associated to a NC PDU set may be based on any of: a dynamic command from the

serving base station, peer receive node or remote receive node, or from the reception of L3, L2 or L1 signaling.

[0513] FIG. 23 is a flowchart illustrating a representative method 2300 implemented by a WTRU. Referring to FIG. 23, the representative method 2300 may include, at block 2310, obtaining a plurality of protocol data units (PDUs) comprising network coded processed data. At block 2320, the representative method 2300 may include, associating with a first PDU from the plurality of PDUs, first information comprising a first identifier of a first PDU set. At block 2330, the representative method 2300 may include associating with a second PDU from the plurality of PDUs, second information comprising a second identifier of a second PDU set. At block 2340, the representative method 2300 may include transmitting the first PDU via a first bearer based on the first identifier. At block 2350, the representative method 2300 may include transmitting the second PDU via a second bearer based on the second identifier.

[0514] In certain representative embodiments, the first identifier may be different from the second identifier on condition that the first PDU and the second PDU are generated from network encoding of different service data units.

[0515] In certain representative embodiments, the representative method 2300 may further comprise: determining that a third PDU from the plurality of PDUs is associated to the first PDU set on condition that the first PDU and the third PDU are generated from network encoding of a same service data unit; associating with the third PDU, third information comprising the first identifier; and/or transmitting the third PDU via the first bearer.

[0516] In certain representative embodiments, the representative method 2300 may further comprise: determining that the first identifier is different from the second identifier using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination.

[0517] In certain representative embodiments, the representative method 2300 may further comprise: determining that a third PDU from the plurality of PDUs is associated to the first PDU set using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination; associating with the third PDU, third information comprising the first identifier; and/or transmitting the third PDU via the first bearer.

[0518] In certain representative embodiments, the network coded processed data may be coded by linear packet coding.

[0519] In certain representative embodiments, any of the first bearer and the second bearer may comprise any of a layer 1 bearer, a layer 2 bearer, and a layer 3 bearer.

[0520] In certain representative embodiments, the representative method 2300 may further comprise: assigning the first PDU to the first bearer and selecting any of (1) at least one layer 2 instance, (2) at least one logical channel, and (3) at least one medium access control layer processing.

[0521] In certain representative embodiments, the first identifier may be included in at least one field in any of (i) a first header of the first PDU and (ii) a second header of a segment of the first PDU.

[0522] In certain representative embodiments, the representative method 2300 may further comprise: assigning the first PDU to the first bearer based on any of scheduling information and transmission parameters.

[0523] Although features and elements are provided 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. The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly provided as such. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods or systems.

[0524] The foregoing embodiments are discussed, for simplicity, with regard to the terminology and structure of infrared capable devices, i.e., infrared emitters and receivers. However, the embodiments discussed are not limited to these systems but may be applied to other systems that use other forms of electromagnetic waves or non-electromagnetic waves such as acoustic waves.

[0525] It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting. As used herein, the term "video" or the term "imagery" may mean any of a snapshot, single image and/or multiple images displayed over a time basis. As another example, when referred to herein, the terms "user equipment" and its abbreviation "UE", the term "remote" and/or the terms "head mounted display" or its abbreviation "HMD" may mean or include (i) a wireless transmit and/or receive unit (WTRU); (ii) any of a

number of embodiments of a WTRU; (iii) a wireless-capable and/or wired-capable (e.g., tetherable) device configured with, inter alia, some or all structures and functionality of a WTRU; (iii) a wireless-capable and/or wired-capable device configured with less than all structures and functionality of a WTRU; or (iv) the like. Details of an example WTRU, which may be representative of any WTRU recited herein, are provided herein with respect to FIGs. 1A-1D. As another example, various disclosed embodiments herein *supra* and *infra* are described as utilizing a head mounted display. Those skilled in the art will recognize that a device other than the head mounted display may be utilized and some or all of the disclosure and various disclosed embodiments can be modified accordingly without undue experimentation. Examples of such other device may include a drone or other device configured to stream information for providing the adapted reality experience.

[0526] In addition, the methods provided 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.

[0527] Variations of the method, apparatus and system provided above are possible without departing from the scope of the invention. In view of the wide variety of embodiments that can be applied, it should be understood that the illustrated embodiments are examples only, and should not be taken as limiting the scope of the following claims. For instance, the embodiments provided herein include handheld devices, which may include or be utilized with any appropriate voltage source, such as a battery and the like, providing any appropriate voltage.

[0528] Moreover, in the embodiments provided above, processing platforms, computing systems, controllers, and other devices that include processors are noted. These devices may include at least one Central Processing Unit ("CPU") and memory. In accordance with the practices of persons skilled in the art of computer programming, reference to acts and symbolic representations of operations or instructions may be performed by the various CPUs and memories. Such acts and operations or instructions may be referred to as being "executed," "computer executed" or "CPU executed."

[0529] One of ordinary skill in the art will appreciate that the acts and symbolically represented operations or instructions include the manipulation of electrical signals by the CPU. An electrical system represents data bits that can cause a resulting transformation or reduction of the electrical signals and the maintenance of data bits at memory locations in a memory system to thereby reconfigure or otherwise alter the CPU's operation, as well as other processing of signals. The memory locations where data bits are maintained are physical locations that have particular electrical, magnetic, optical, or organic properties corresponding to or representative of the data bits. It should be understood that the embodiments are not limited to the above-mentioned platforms or CPUs and that other platforms and CPUs may support the provided methods.

[0530] The data bits may also be maintained on a computer readable medium including magnetic disks, optical disks, and any other volatile (e.g., Random Access Memory (RAM)) or non-volatile (e.g., Read-Only Memory (ROM)) mass storage system readable by the CPU. The computer readable medium may include cooperating or interconnected computer readable medium, which exist exclusively on the processing system or are distributed among multiple interconnected processing systems that may be local or remote to the processing system. It should be understood that the embodiments are not limited to the above-mentioned memories and that other platforms and memories may support the provided methods.

[0531] In an illustrative embodiment, any of the operations, processes, etc. described herein may be implemented as computer-readable instructions stored on a computer-readable medium. The computer-readable instructions may be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[0532] There is little distinction left between hardware and software implementations of aspects of systems. The use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software may become significant) a design choice representing cost versus efficiency tradeoffs. There may be various vehicles by which processes and/or systems and/or other technologies described herein may be effected (e.g., hardware, software, and/or firmware), and the preferred vehicle may vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle. If flexibility is paramount, the implementer may opt for a mainly software implementation. Alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[0533] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block

diagrams, flowcharts, and/or examples include one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples may be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In an embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), and/or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, may be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein may be distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc., and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0534] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein may be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system may generally include one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity, control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing

any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0535] The herein described subject matter sometimes illustrates different components included within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality may be achieved. Hence, any two components herein combined to achieve a particular functionality may be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated may also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated may also be viewed as being "operably couplable" to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0536] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0537] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, where only one item is intended, the term "single" or similar language may be used. As an aid to understanding, the following appended claims and/or the descriptions herein may include usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim including such introduced claim recitation to embodiments including only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an"

(e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"). The same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, the terms "any of" followed by a listing of a plurality of items and/or a plurality of categories of items, as used herein, are intended to include "any of," "any combination of," "any multiple of," and/or "any combination of multiples of" the items and/or the categories of items, individually or in conjunction with other items and/or other categories of items. Moreover, as used herein, the term "set" is intended to include any number of items, including zero. Additionally, as used herein, the term "number" is intended to include any number, including zero. And the term "multiple", as used herein, is intended to be synonymous with "a plurality".

[0538] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0539] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein may be

readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," and the like includes the number recited and refers to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0540] Moreover, the claims should not be read as limited to the provided order or elements unless stated to that effect. In addition, use of the terms "means for" in any claim is intended to invoke 35 U.S.C. §112, ¶ 6 or means-plus-function claim format, and any claim without the terms "means for" is not so intended.

CLAIMS

What is claimed is:

1. A method implemented by a wireless transmit/receive unit (WTRU), the method comprising:
 - obtaining a plurality of protocol data units (PDUs) comprising network coded processed data;
 - associating with a first PDU from the plurality of PDUs, first information comprising a first identifier of a first PDU set;
 - associating with a second PDU from the plurality of PDUs, second information comprising a second identifier of a second PDU set;
 - transmitting the first PDU via a first bearer based on the first identifier; and
 - transmitting the second PDU via a second bearer based on the second identifier.
2. The method according to claim 1, wherein the first identifier is different from the second identifier on condition that the first PDU and the second PDU are generated from network encoding of different service data units.
3. The method according to any of claims 1-2, further comprising:
 - determining that a third PDU from the plurality of PDUs is associated to the first PDU set on condition that the first PDU and the third PDU are generated from network encoding of a same service data unit;
 - associating with the third PDU, third information comprising the first identifier; and
 - transmitting the third PDU via the first bearer.
4. The method according to claim 1, further comprising: determining that the first identifier is different from the second identifier using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination.
5. The method according to any of claims 1-2, further comprising:
 - determining that a third PDU from the plurality of PDUs is associated to the first PDU set using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination;
 - associating with the third PDU, third information comprising the first identifier; and
 - transmitting the third PDU via the first bearer.
6. The method according to any of claims 1-5, wherein the network coded processed data are coded by linear packet coding.

7. The method according to any of claims 1-6, wherein any of the first bearer and the second bearer comprises any of a layer 1 bearer, a layer 2 bearer, and a layer 3 bearer.
8. The method according to claim 7, further comprising assigning the first PDU to the first bearer and selecting any of (1) at least one layer 2 instance, (2) at least one logical channel, and (3) at least one medium access control layer processing.
9. The method according to any of claims 1-8, wherein the first identifier is included in at least one field in any of (i) a first header of the first PDU and (ii) a second header of a segment of the first PDU.
10. The method according to any of claims 1-9, further comprising assigning the first PDU to the first bearer based on any of scheduling information and transmission parameters.
11. A wireless transmit/receive unit (WTRU) comprising circuitry, including a transmitter, a receiver, a processor and memory, the WTRU configured to:
- obtain a plurality of protocol data units (PDUs) comprising network coded processed data;
 - associate with a first PDU from the plurality of PDUs, first information comprising a first identifier of a first PDU set;
 - associate with a second PDU from the plurality of PDUs, second information comprising a second identifier of a second PDU set;
 - transmit the first PDU via a first bearer based on the first identifier; and
 - transmit the second PDU via a second bearer based on the second identifier.
12. The WTRU of claim 11, wherein the first identifier is different from the second identifier on condition that the first PDU and the second PDU are generated from network encoding of different service data units.
13. The WTRU according to any of claims 11-12, further configured to:
- determine that a third PDU from the plurality of PDUs is associated to the first PDU set on condition that the first PDU and the third PDU are generated from network encoding of a same service data unit;
 - associating with the third PDU, third information comprising the first identifier; and
 - transmitting the third PDU via the first bearer.

14. The WTRU according to claim 11, further configured to: determine that the first identifier is different from the second identifier using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination.

15. The WTRU according to any of claims 11-12, further configured to:

determine that a third PDU from the plurality of PDUs is associated to the first PDU set using any of (1) a semi-static configuration, (2) a dynamic signaling, and (3) a WTRU-autonomous determination;

associate with the third PDU, third information comprising the first identifier; and

transmit the third PDU via the first bearer.

16. The WTRU according to any of claims 11-15, wherein the network coded processed data are coded by linear packet coding.

17. The WTRU according to any of claims 11-16, wherein any of the first bearer and the second bearer comprises any of a layer 1 bearer, a layer 2 bearer, and a layer 3 bearer.

18. The WTRU according to claim 17, further configured to assign the first PDU to the first bearer and select any of (1) at least one layer 2 instance, (2) at least one logical channel, and (3) at least one medium access control layer processing.

19. The WTRU according to any of claims 11-18, wherein the identifier of the first PDU set is included in at least one field in any of (i) a first header of the first PDU and (ii) a second header of a segment of the first PDU.

20. The WTRU according to any of claims 11-19, further configured to assign the first PDU to the first bearer based on any of scheduling information and transmission parameters.

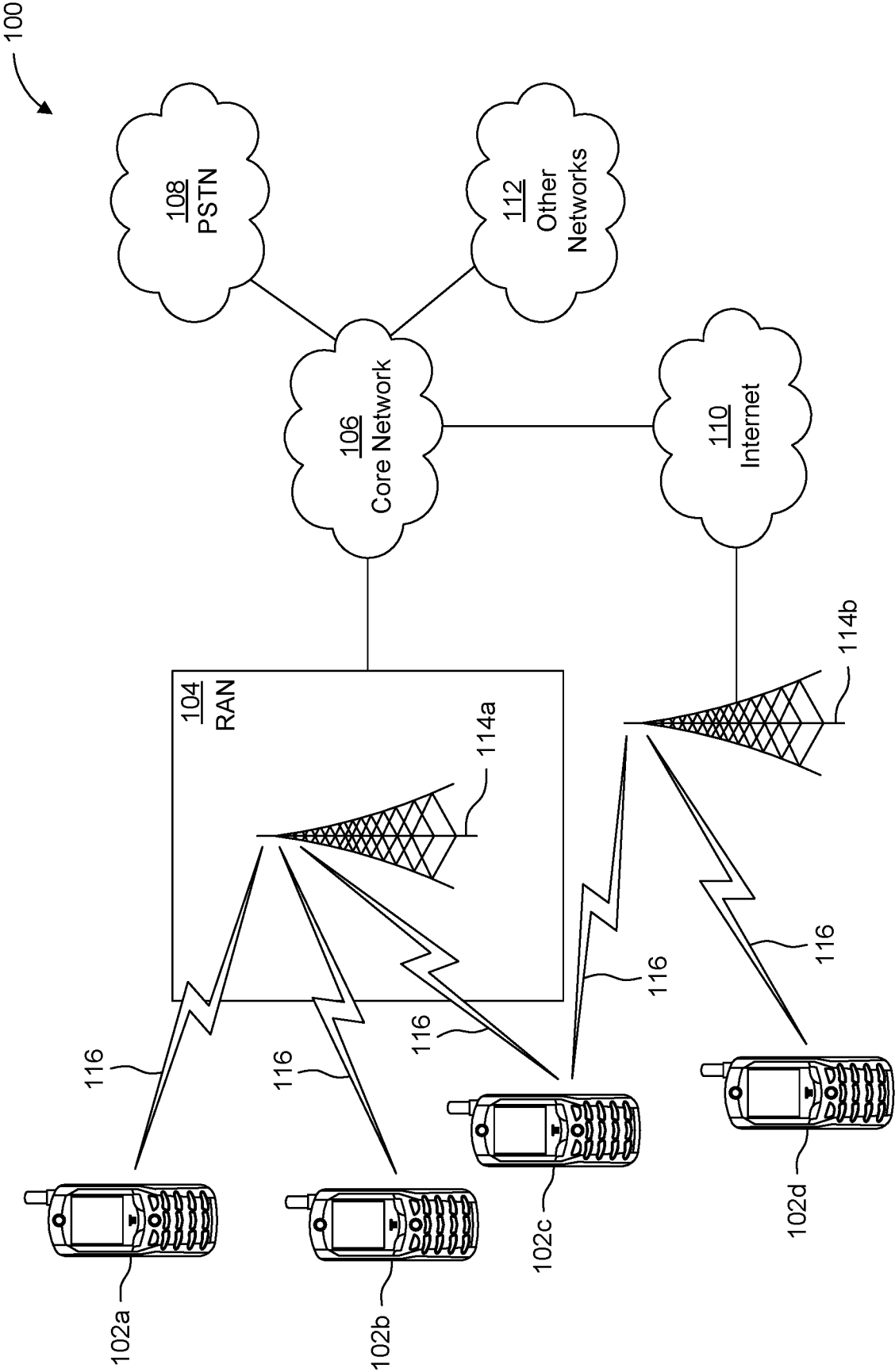


FIG. 1A

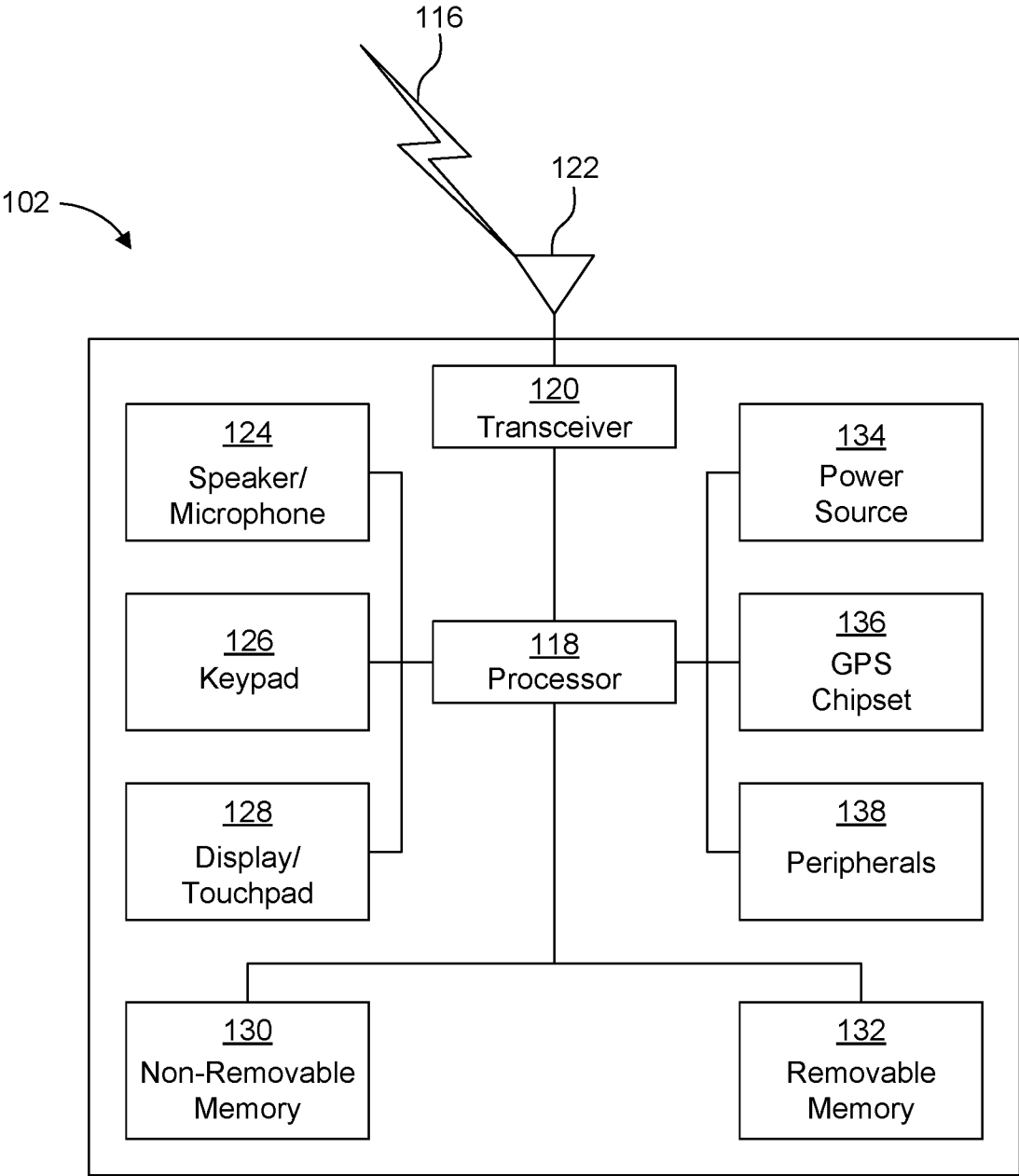


FIG. 1B

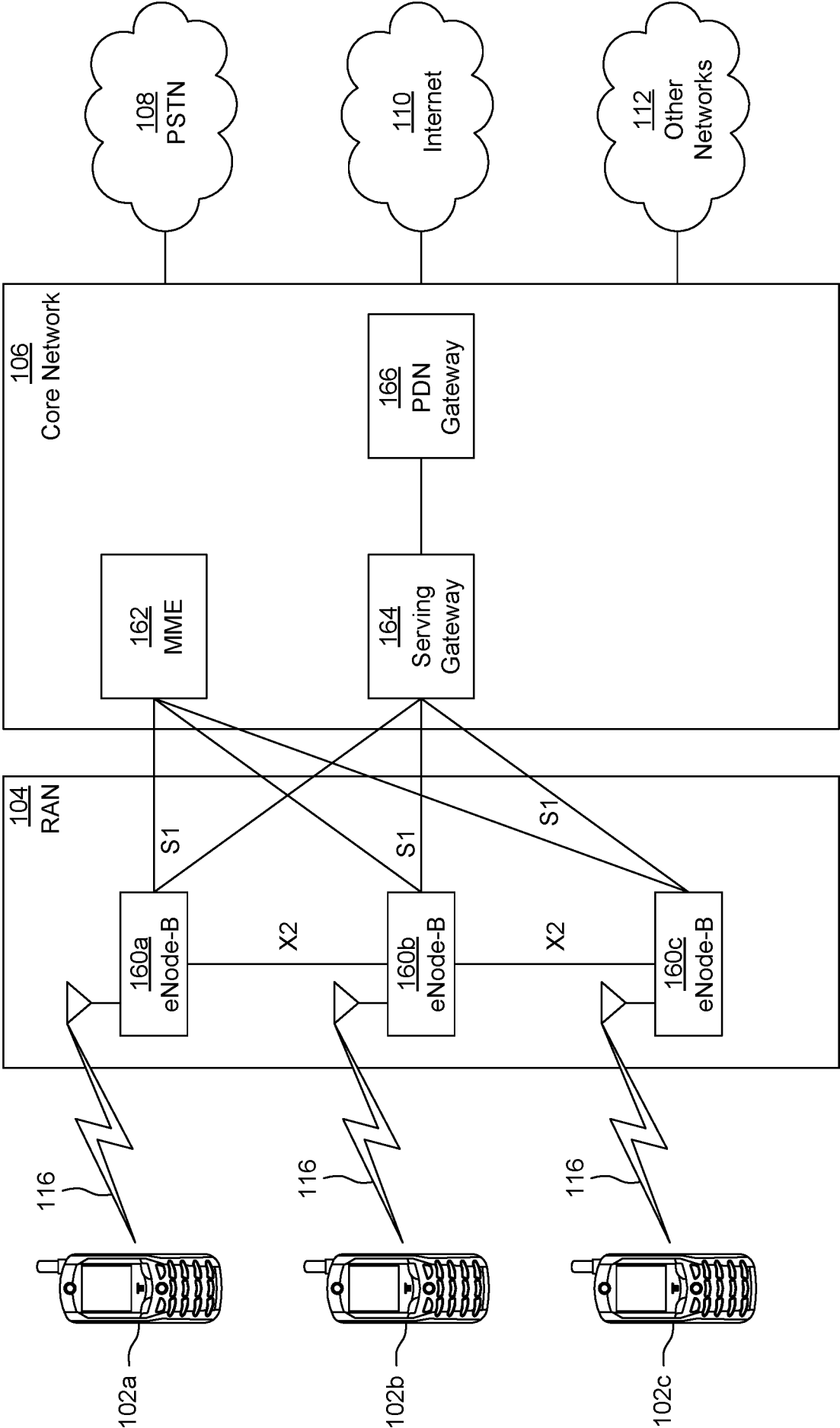


FIG. 1C

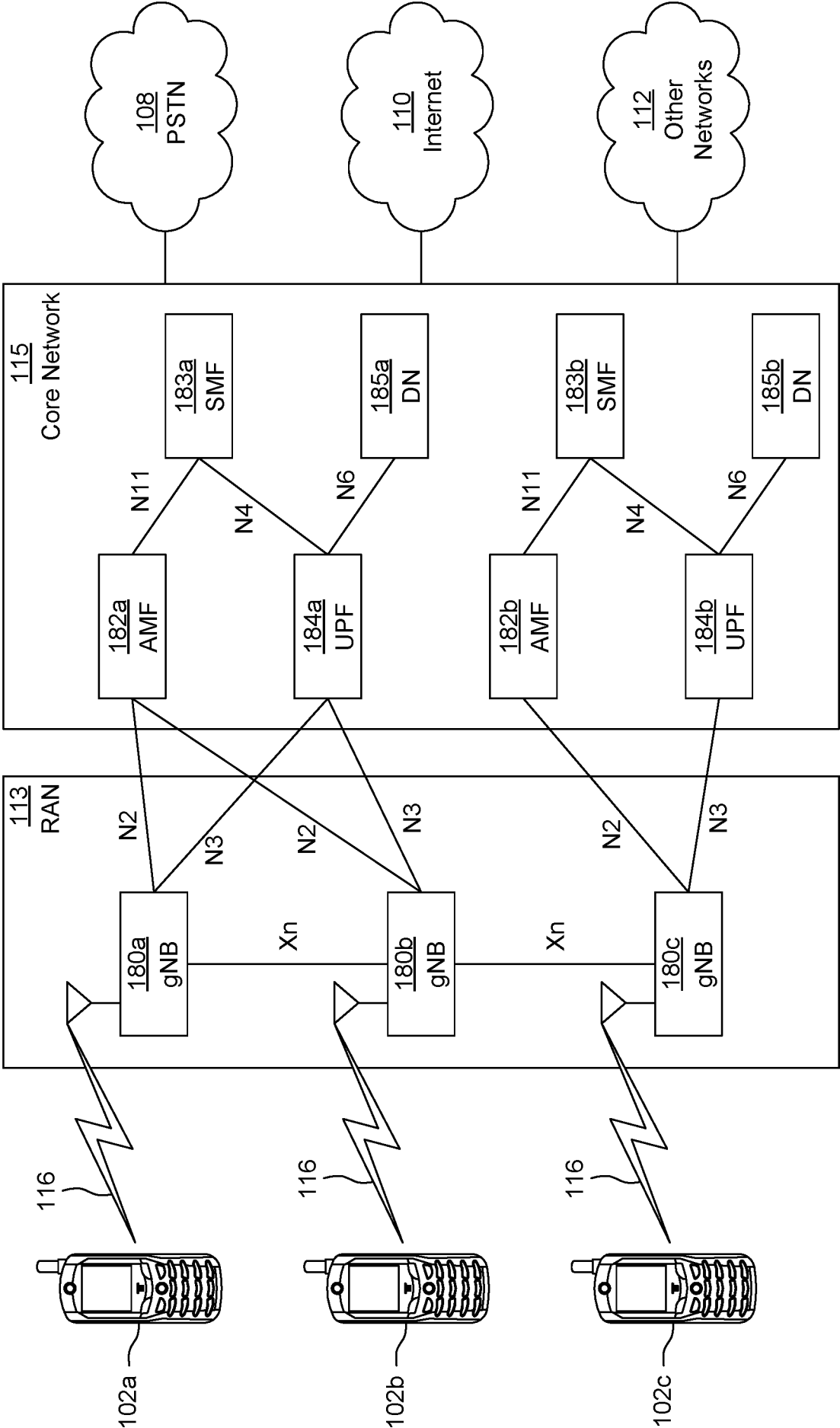


FIG. 1D

$$\left\{ \begin{array}{cccc} C_{1,1} & \dots & C_{1,l} & \dots & C_{1,m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{k,1} & \vdots & C_{k,l} & \vdots & C_{k,m} \\ C_{k+1,1} & \vdots & C_{k+1,l} & \vdots & C_{k+1,m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_{r,1} & \dots & C_{r,l} & \dots & C_{r,m} \end{array} \right\} = \left\{ \begin{array}{cccc} g_{1,1} & \dots & g_{1,j} & \dots & g_{1,k} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ g_{k,1} & \dots & g_{k,j} & \dots & g_{k,k} \\ g_{k+1,1} & \dots & g_{k+1,j} & \dots & g_{k+1,k} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ g_{r,1} & \dots & g_{r,j} & \dots & g_{r,k} \end{array} \right\} \left\{ \begin{array}{cccc} p_{1,1} & \dots & p_{1,l} & \dots & p_{1,m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{k,1} & \dots & p_{k,l} & \dots & p_{k,m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ p_{k,1} & \dots & p_{k,l} & \dots & p_{k,m} \end{array} \right\}$$

FIG. 2

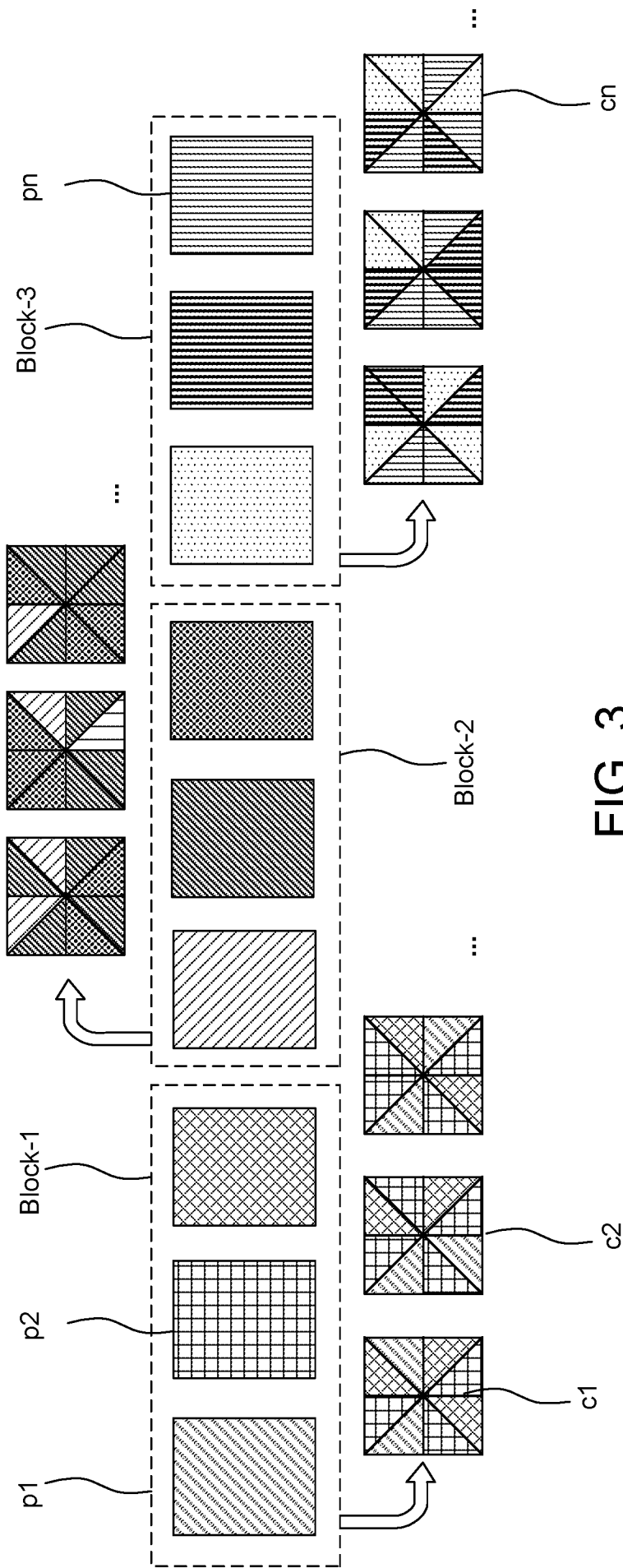


FIG. 3

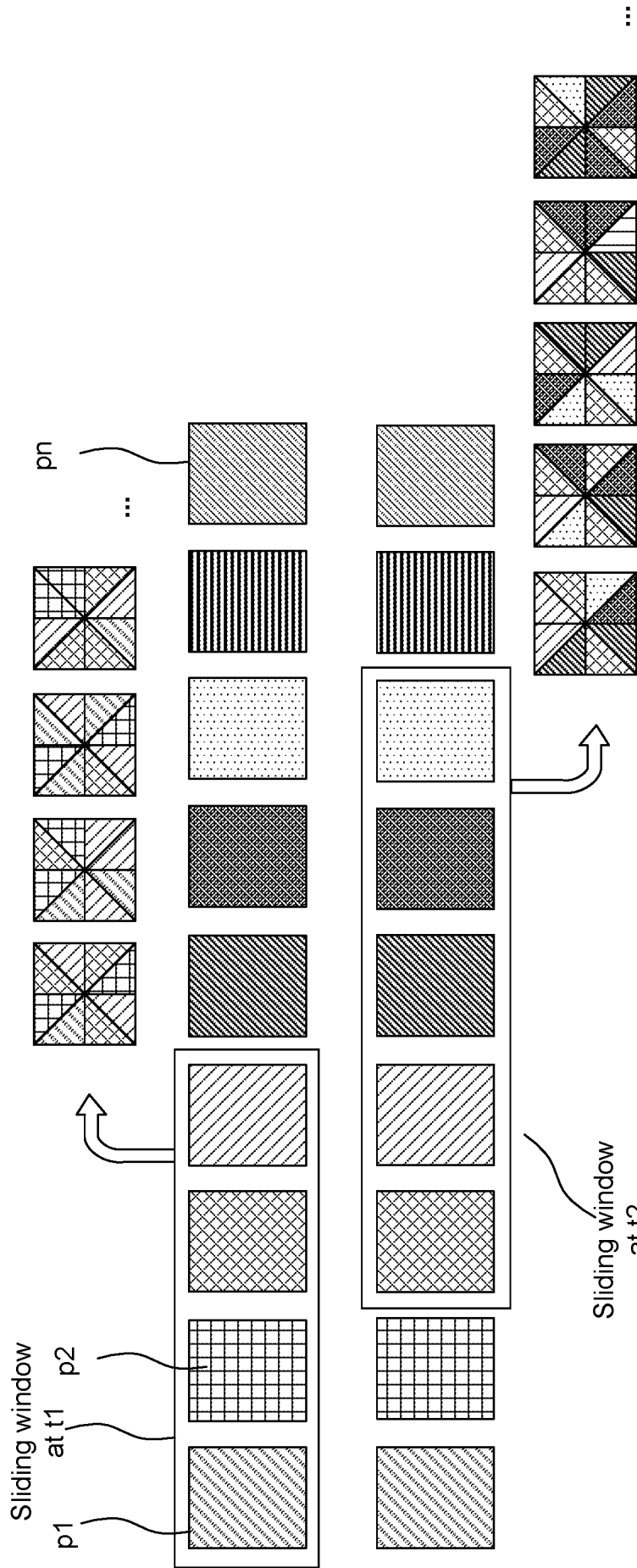


FIG. 4

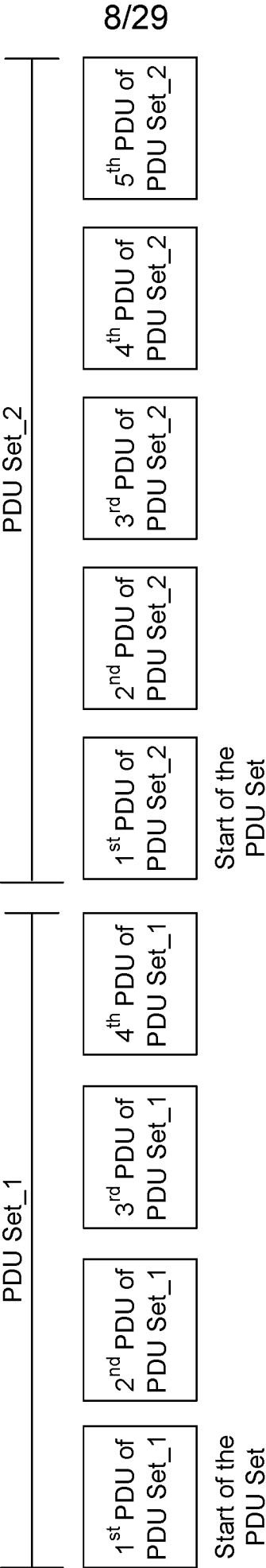


FIG. 5

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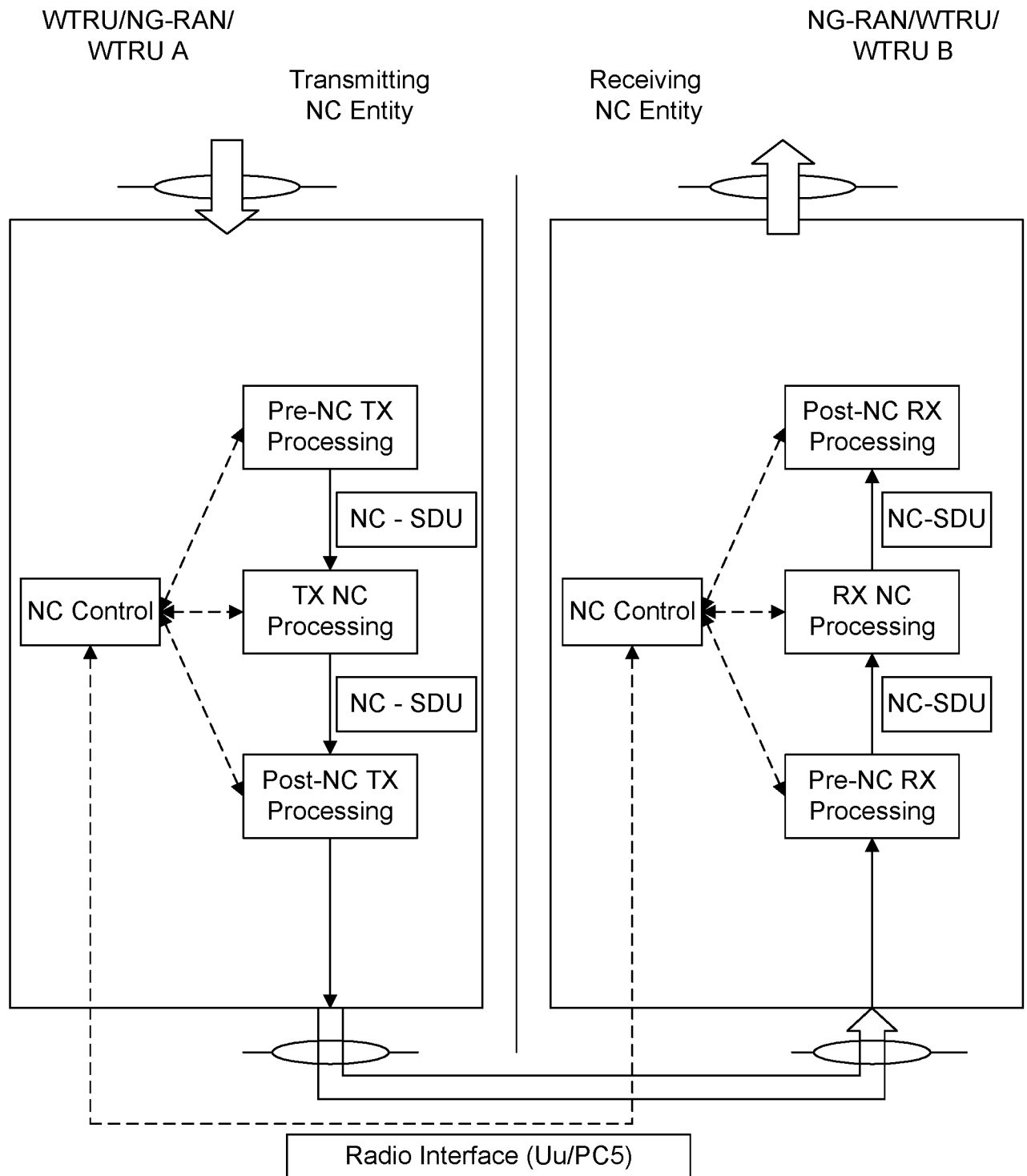


FIG. 6

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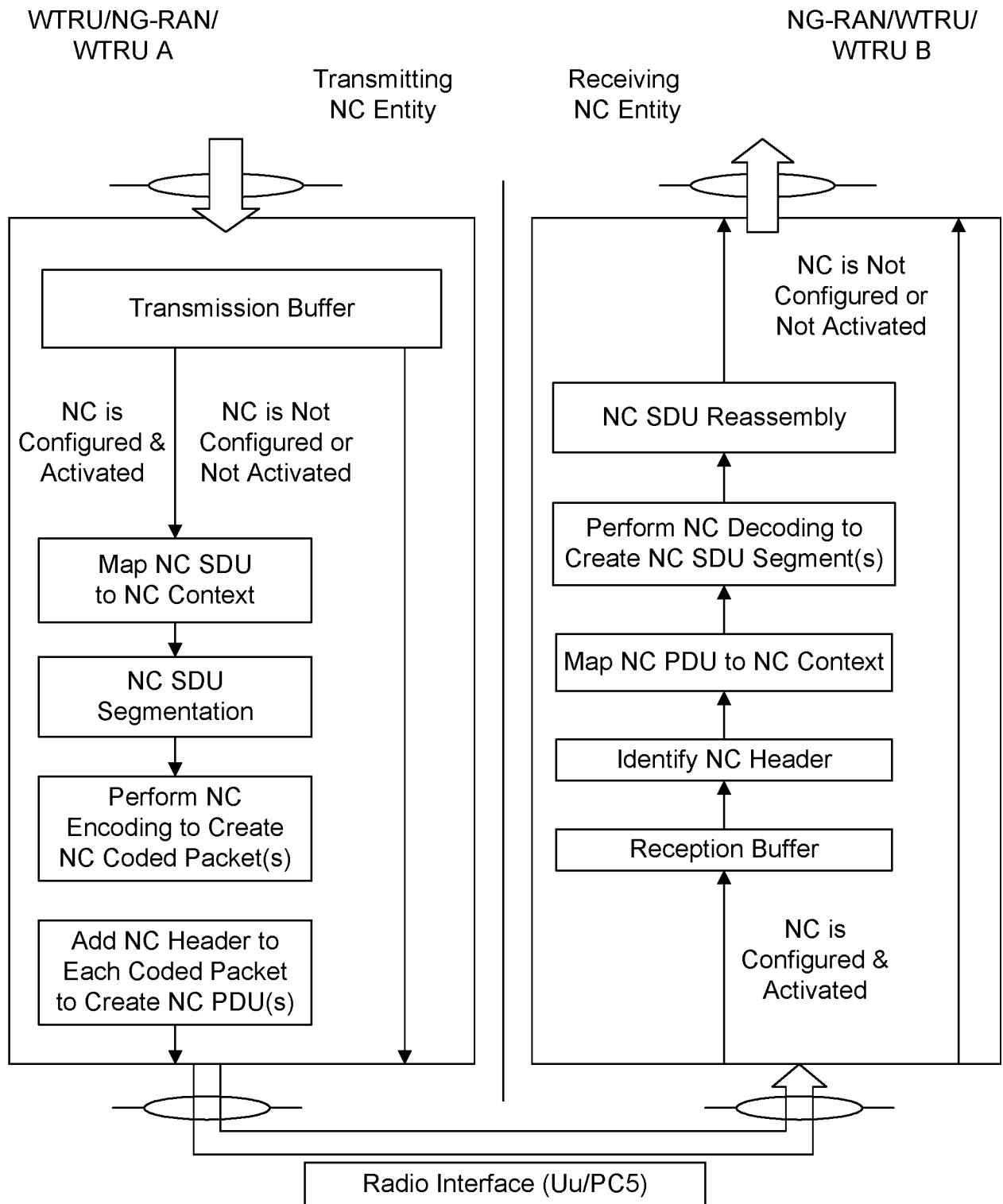


FIG. 7

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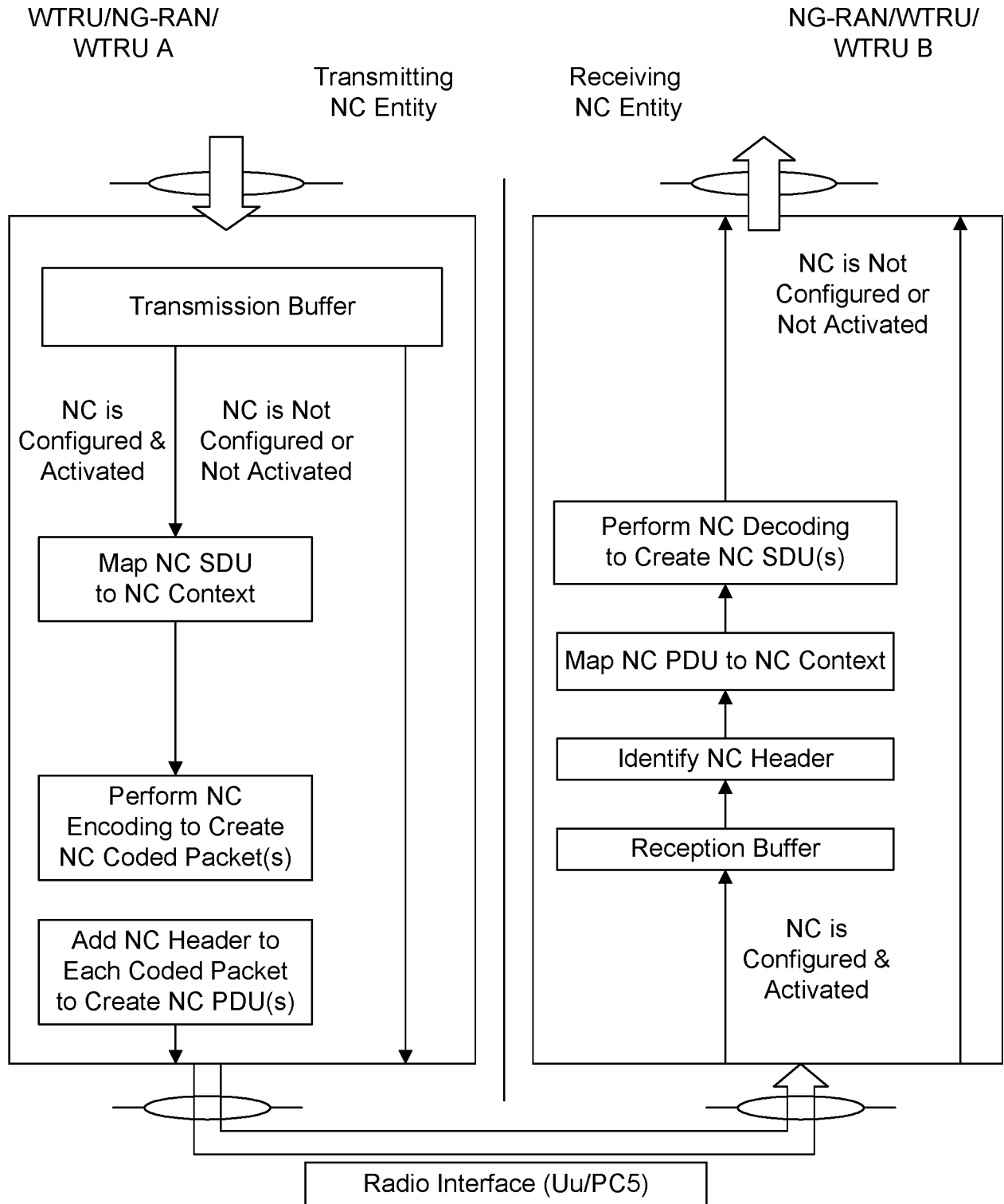


FIG. 8

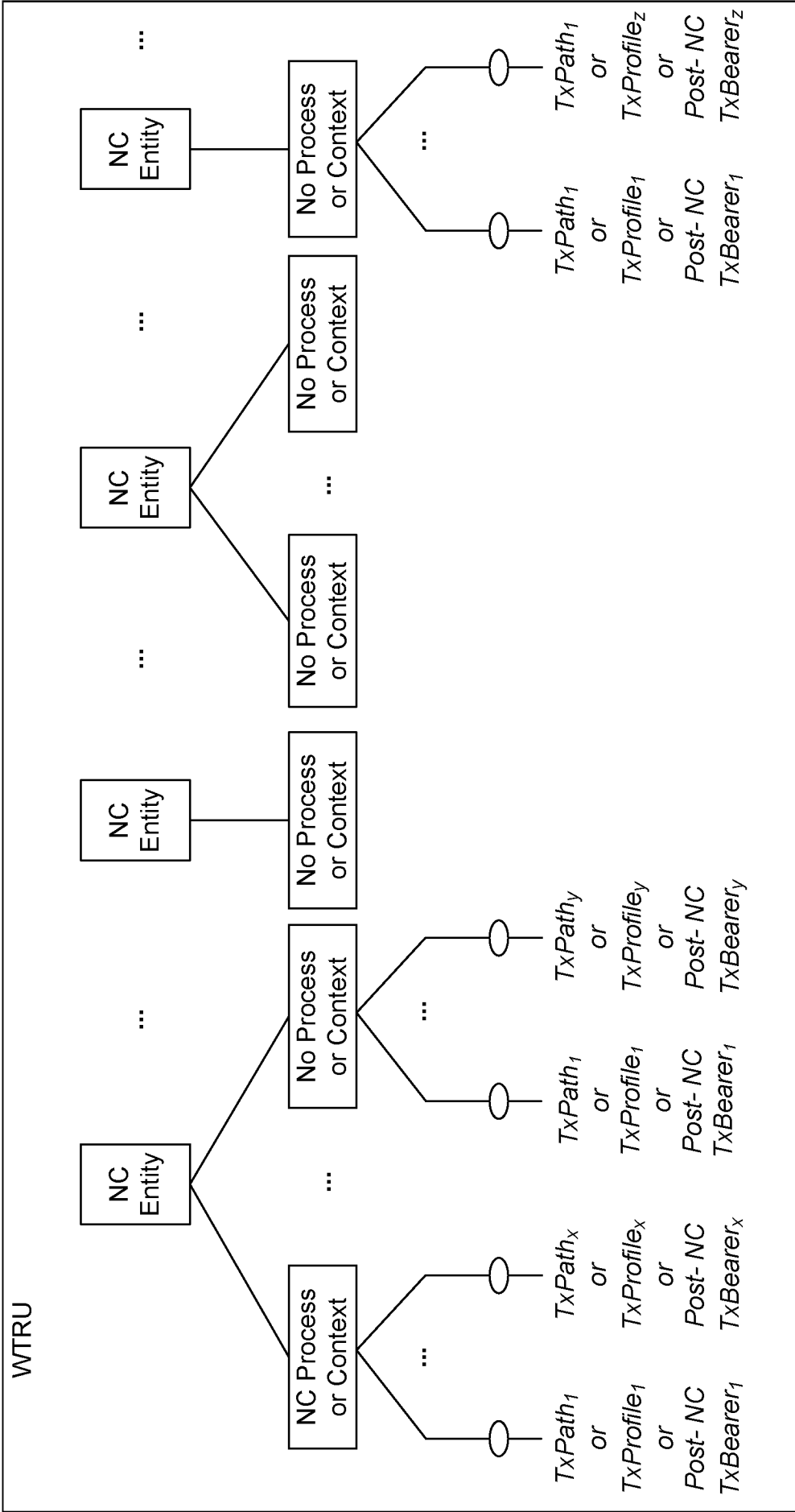


FIG. 9

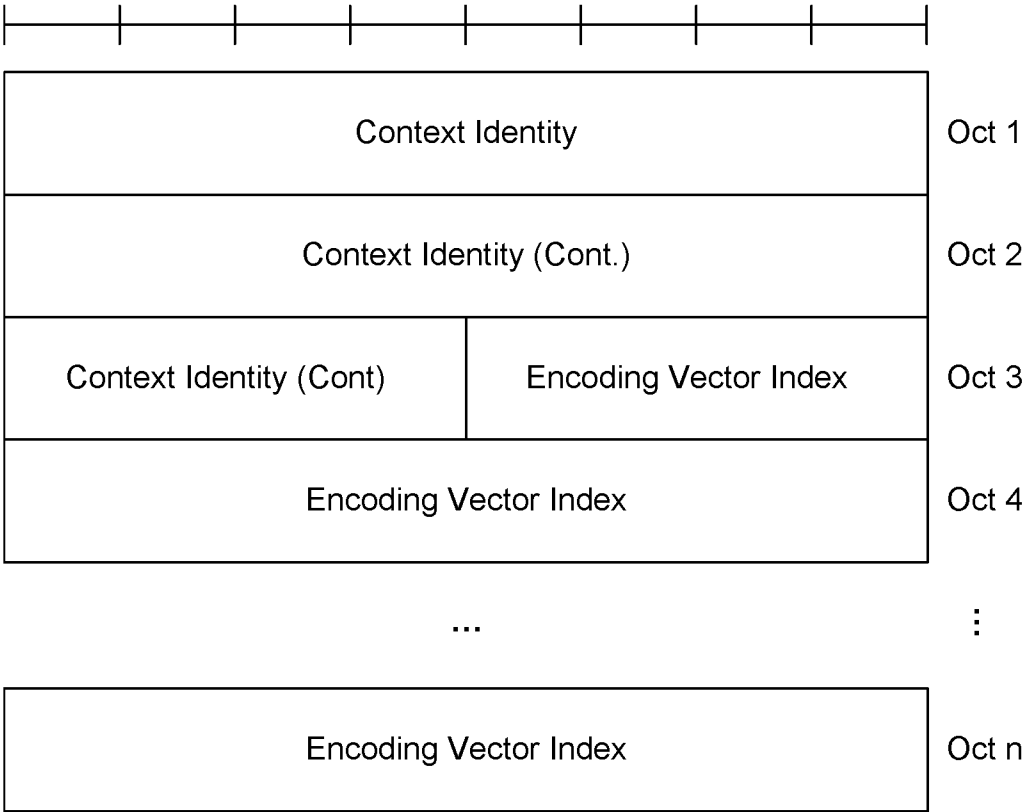


FIG. 10

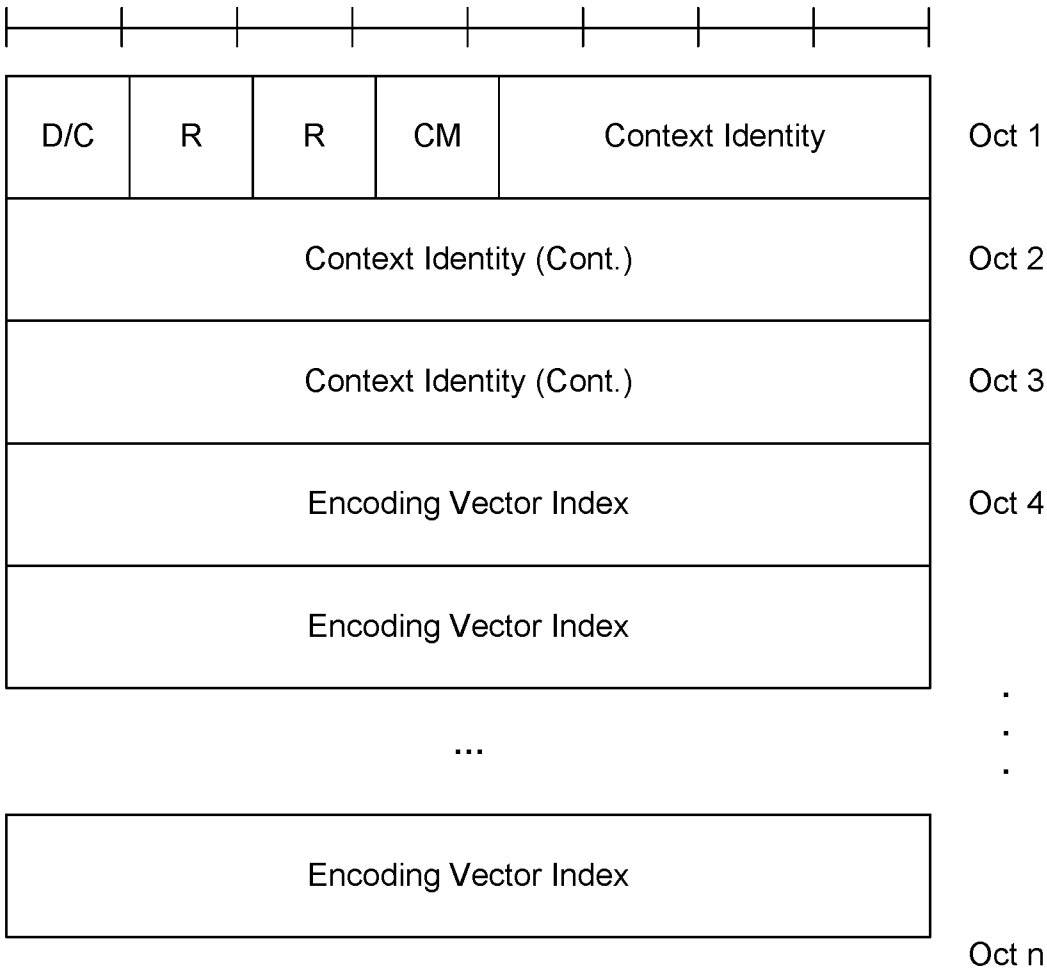


FIG. 11

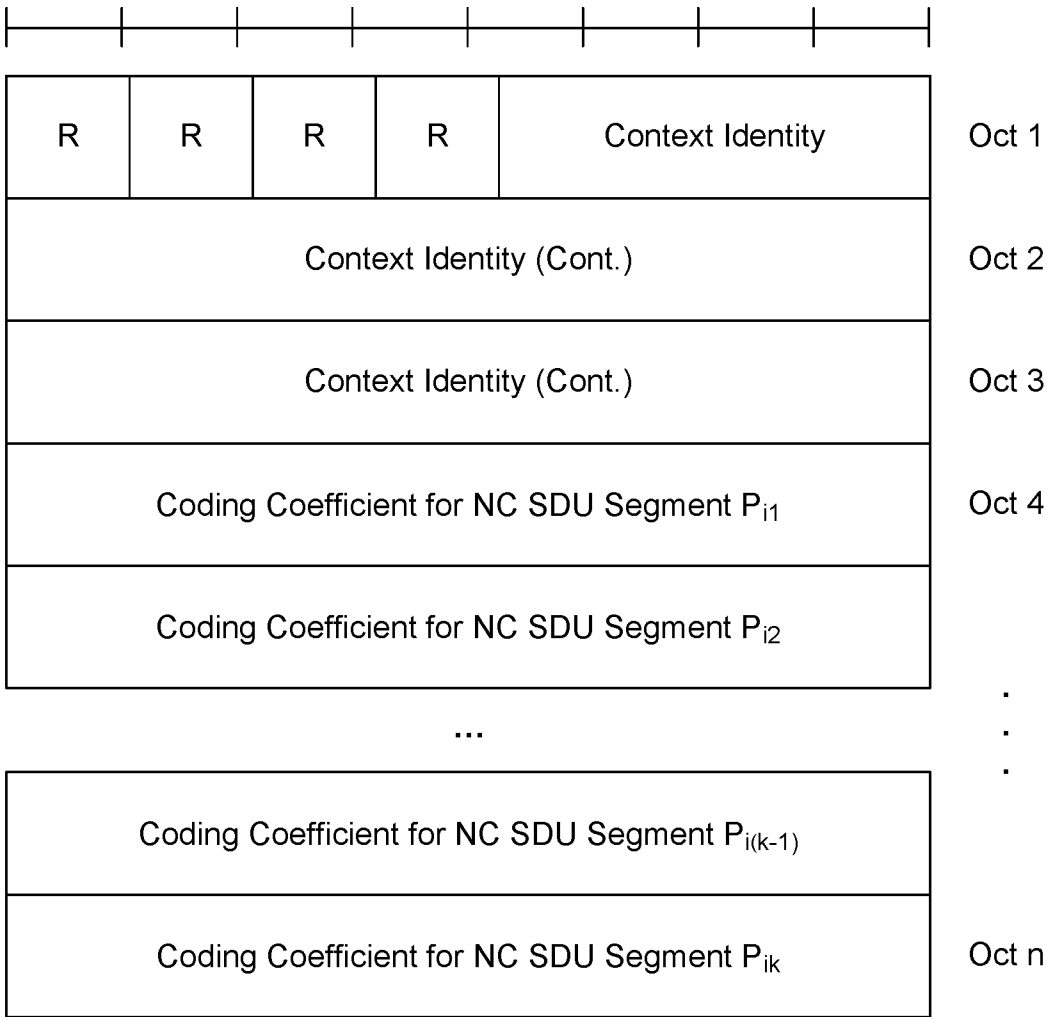


FIG. 12

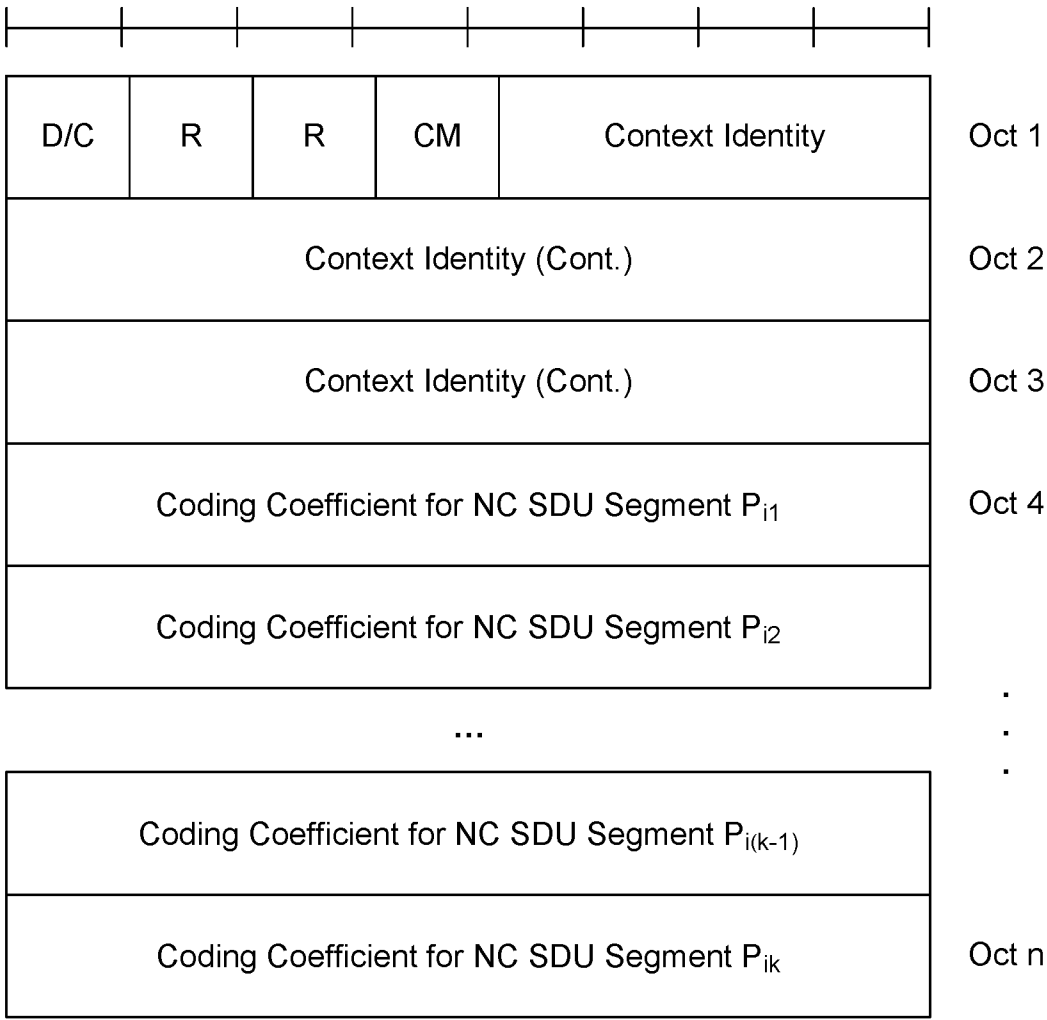


FIG. 13

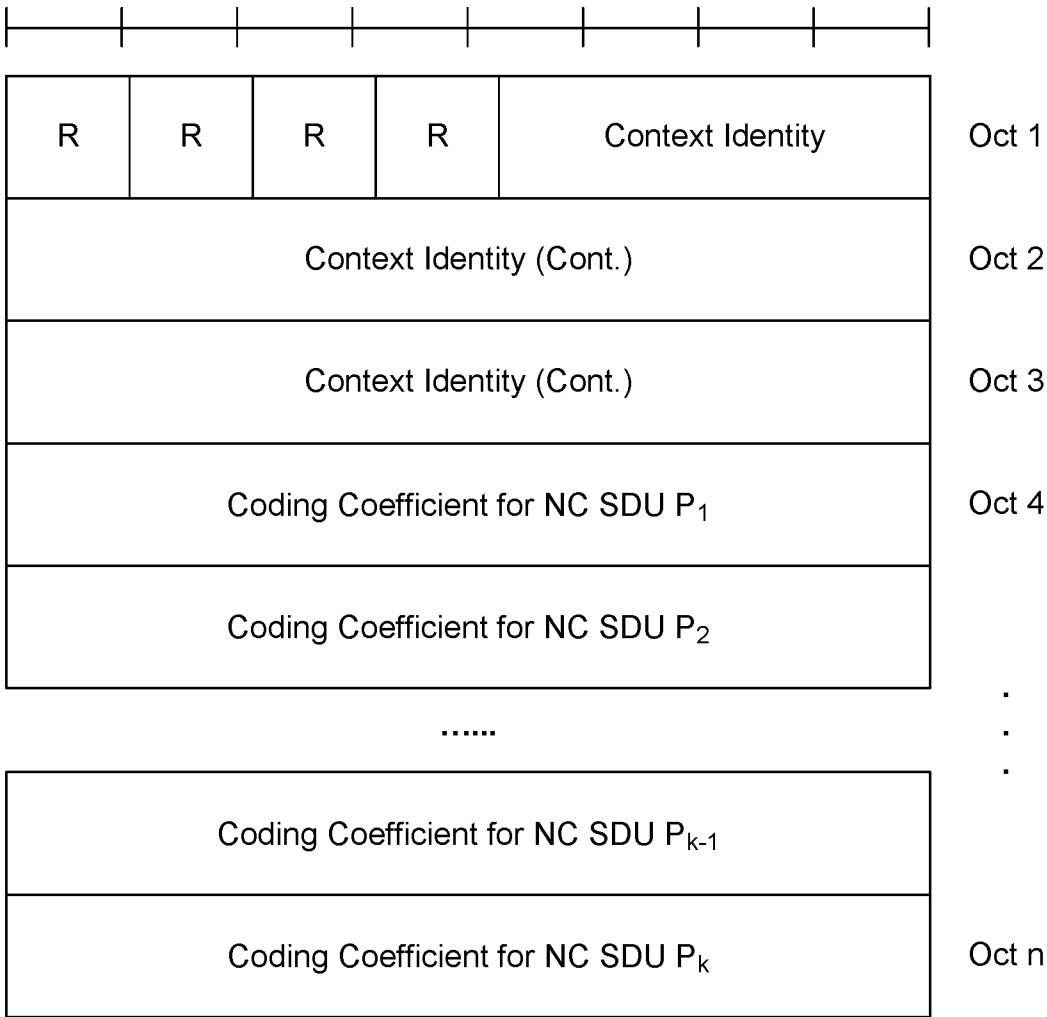


FIG. 14

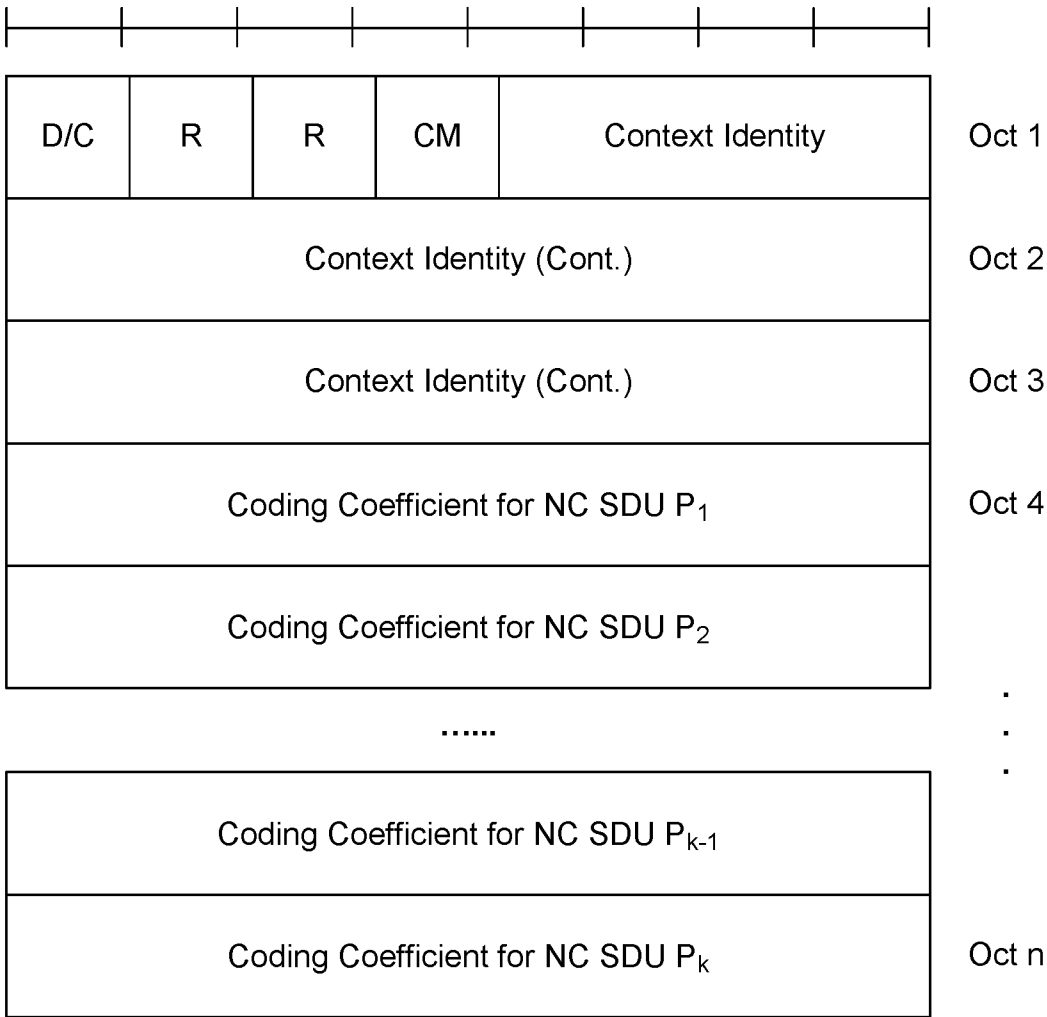


FIG. 15

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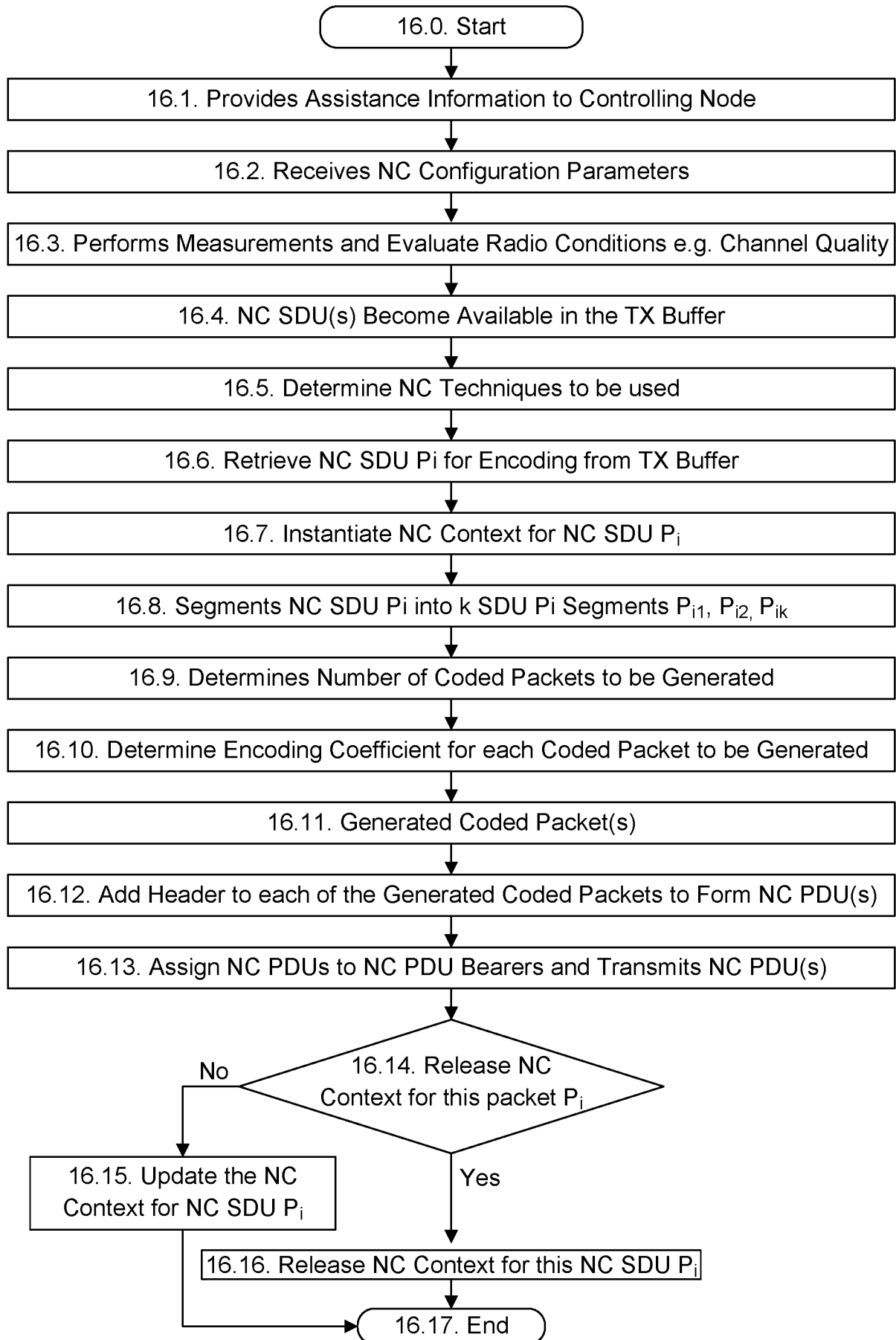


FIG. 16

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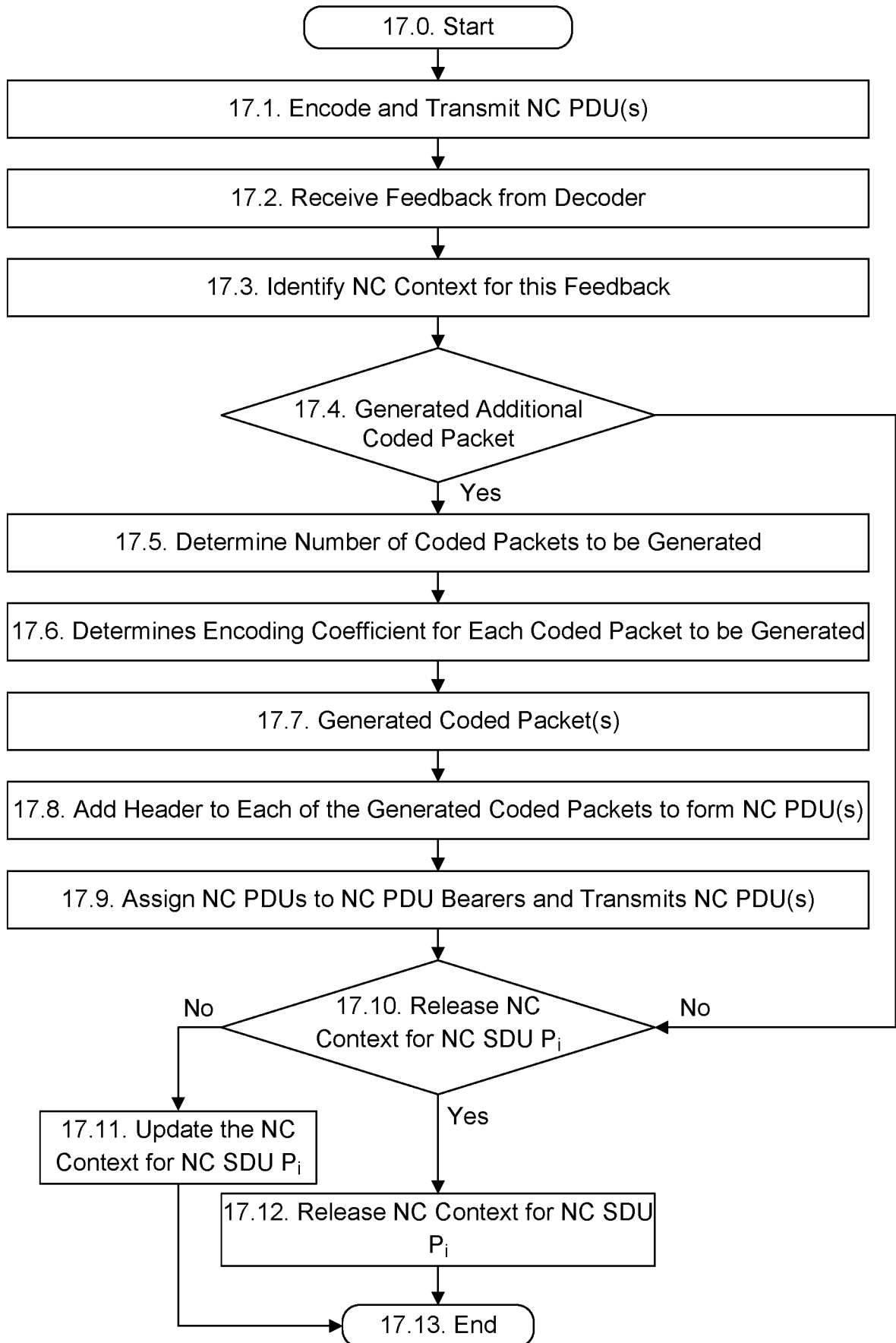


FIG. 17

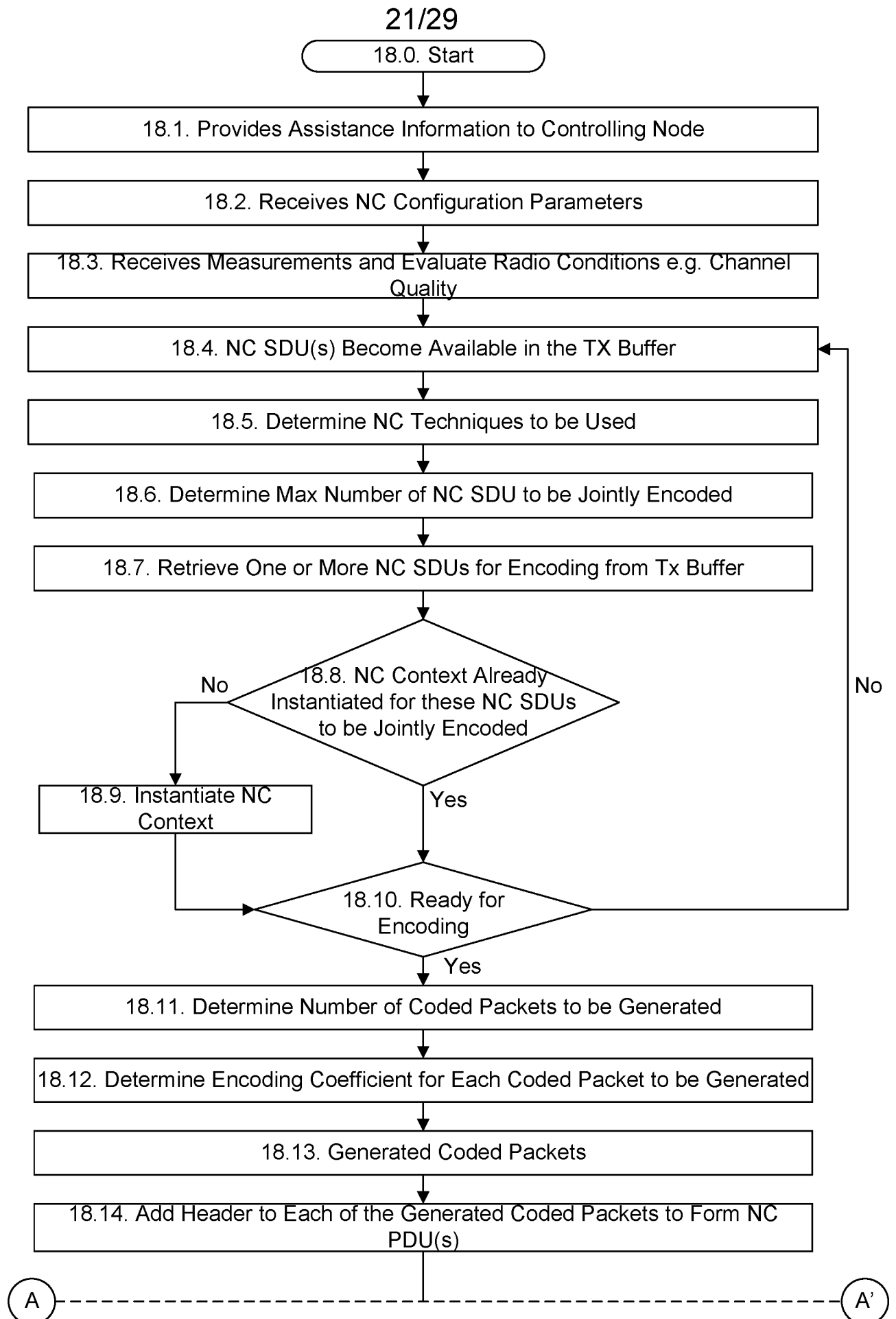


FIG. 18

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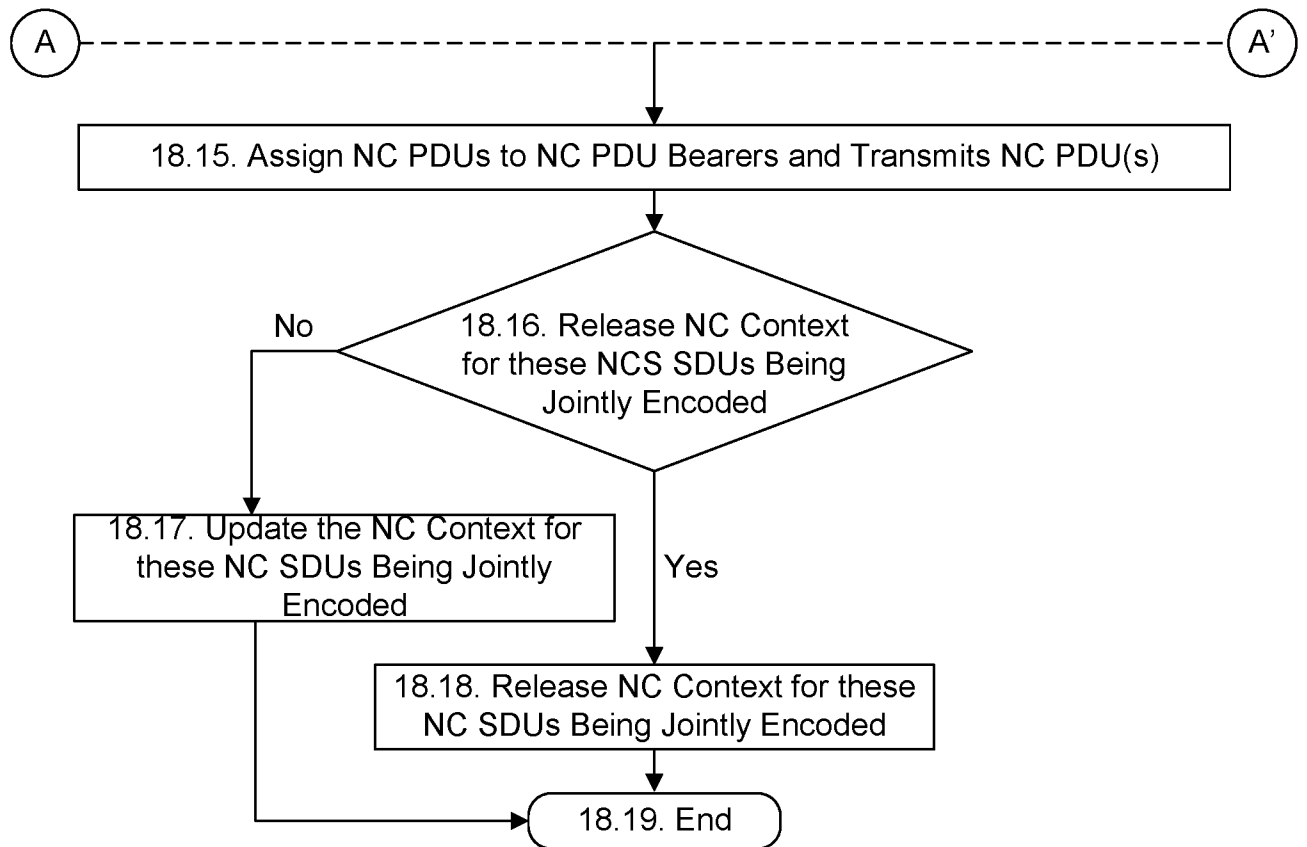


FIG. 18 (Continued)

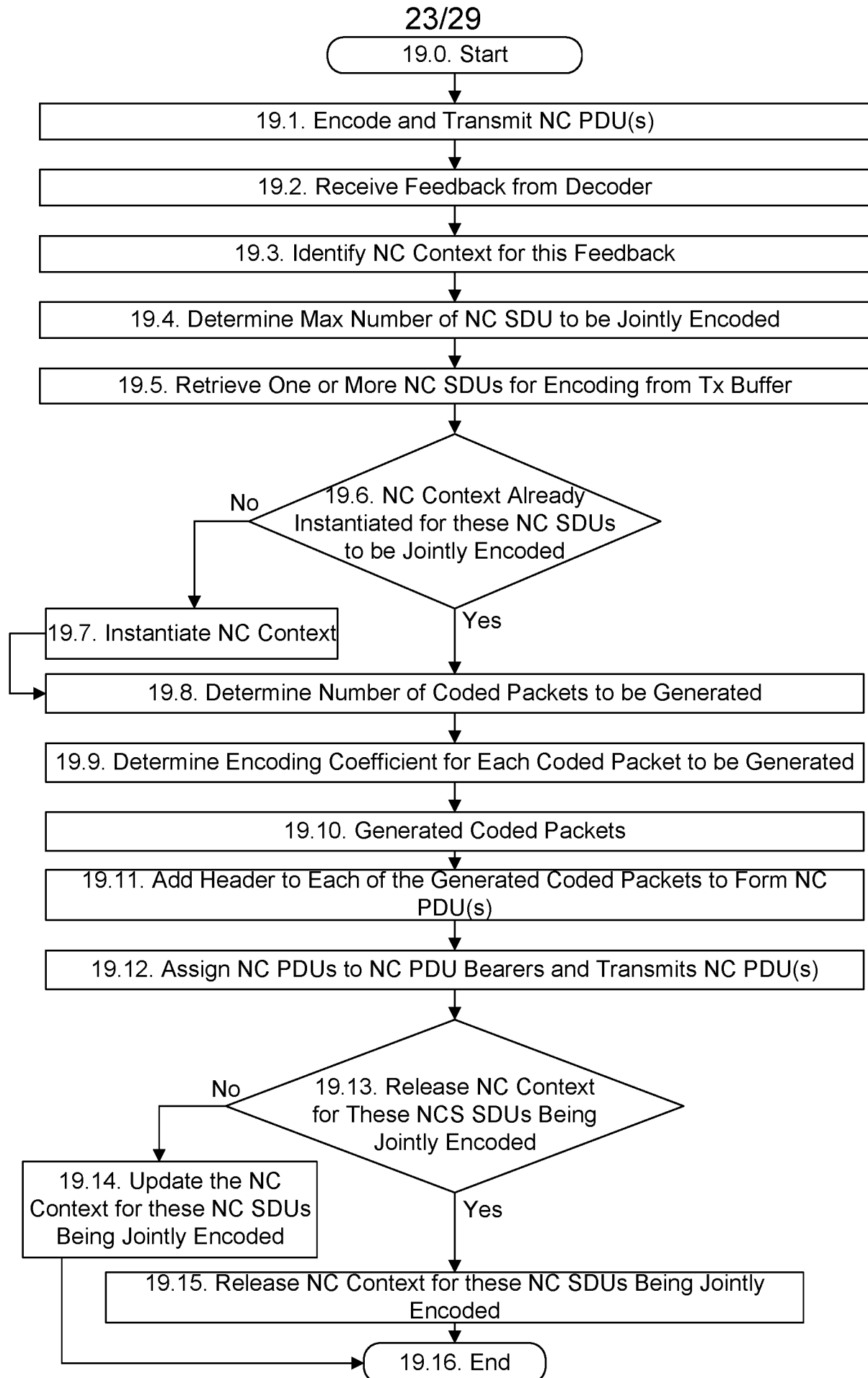


FIG. 19

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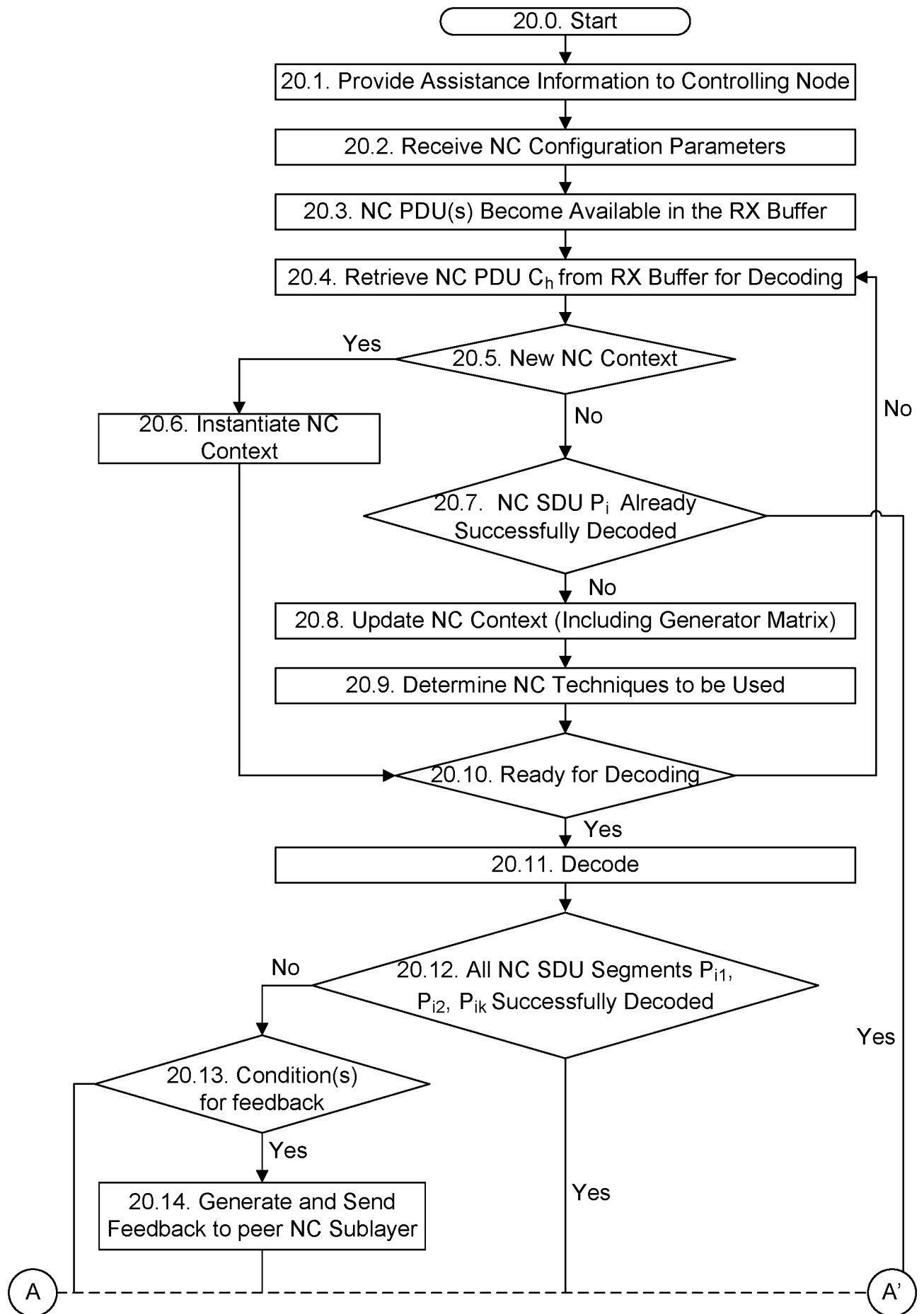


FIG. 20

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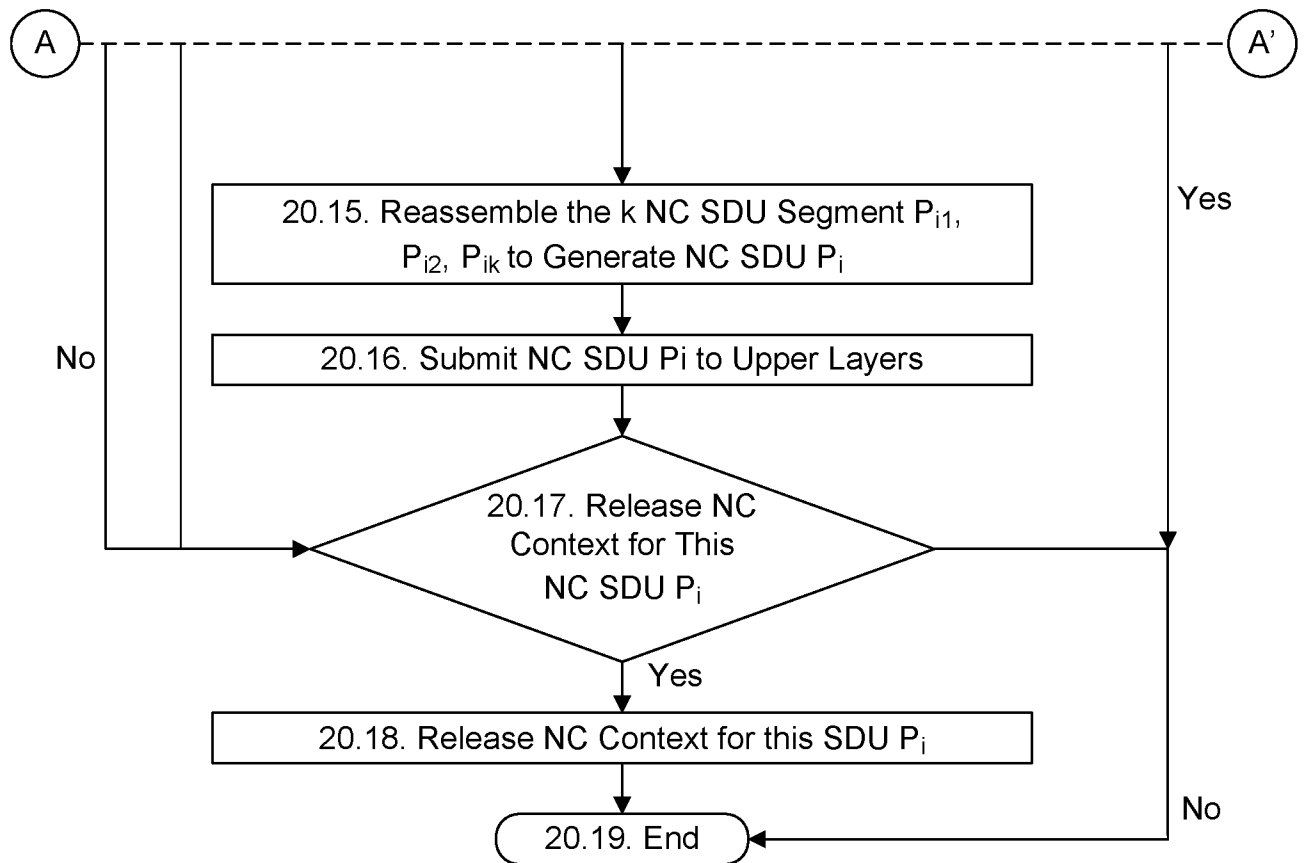


FIG. 20 (Continued)

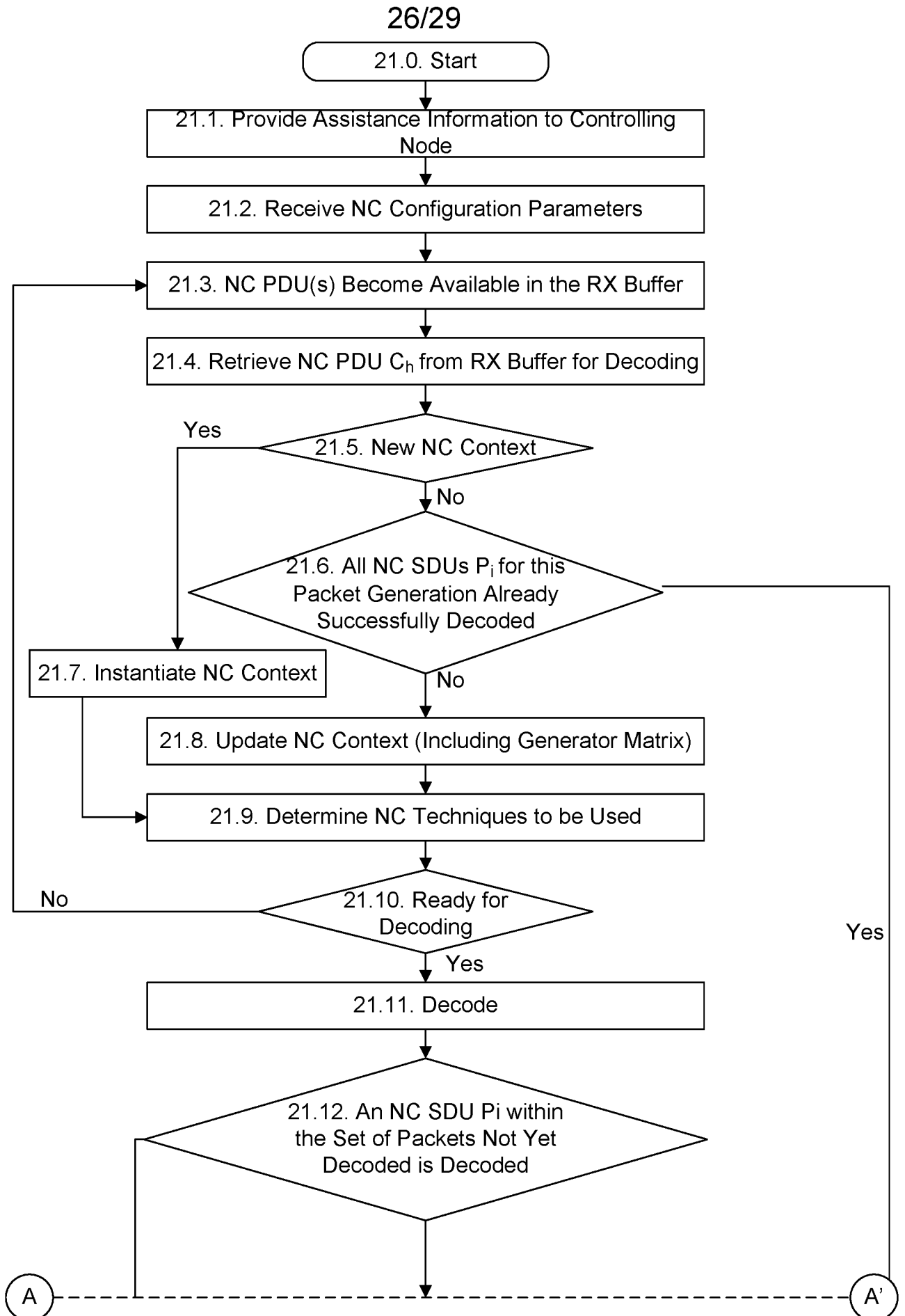


FIG. 21

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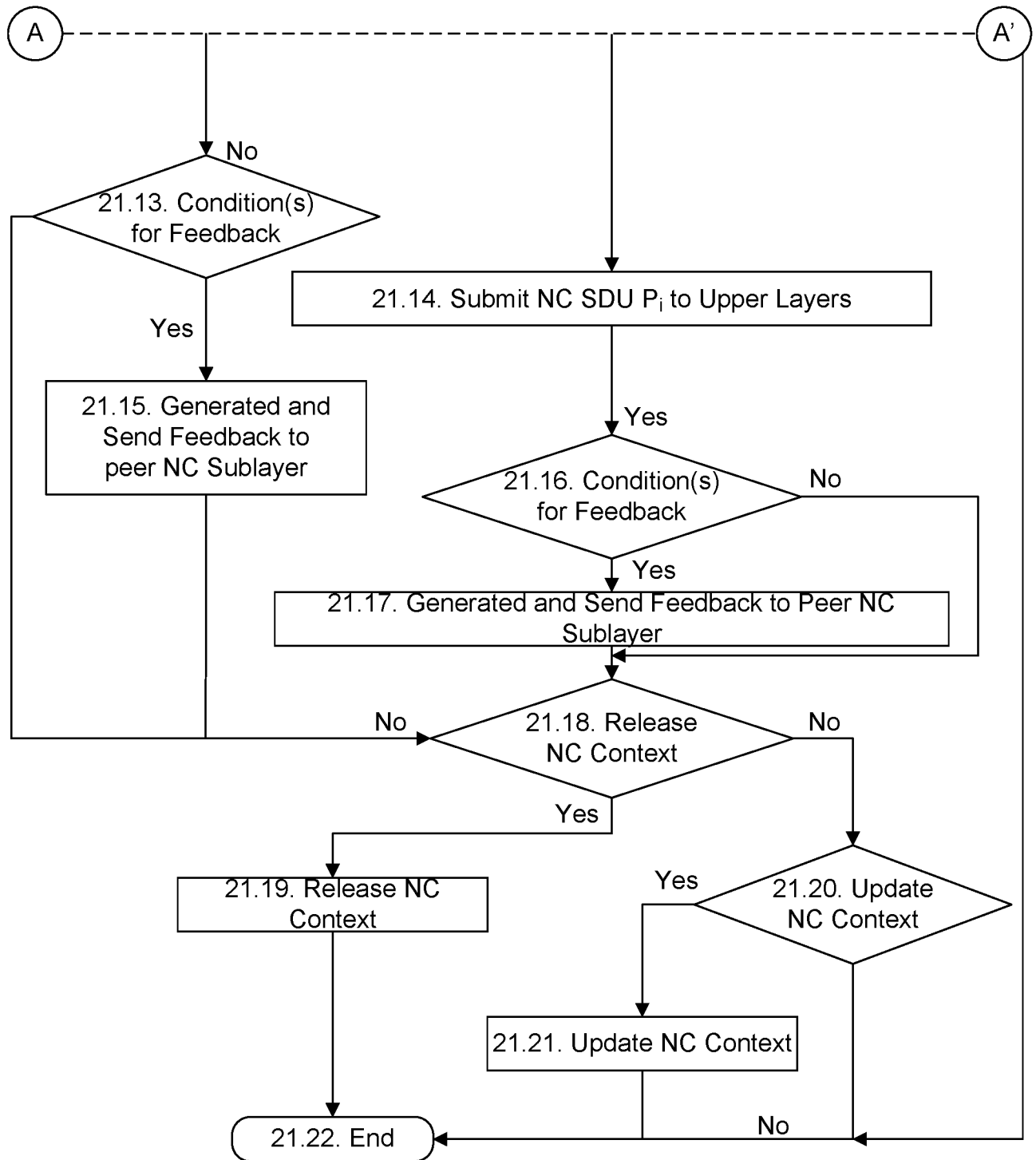


FIG. 21 (Continued)

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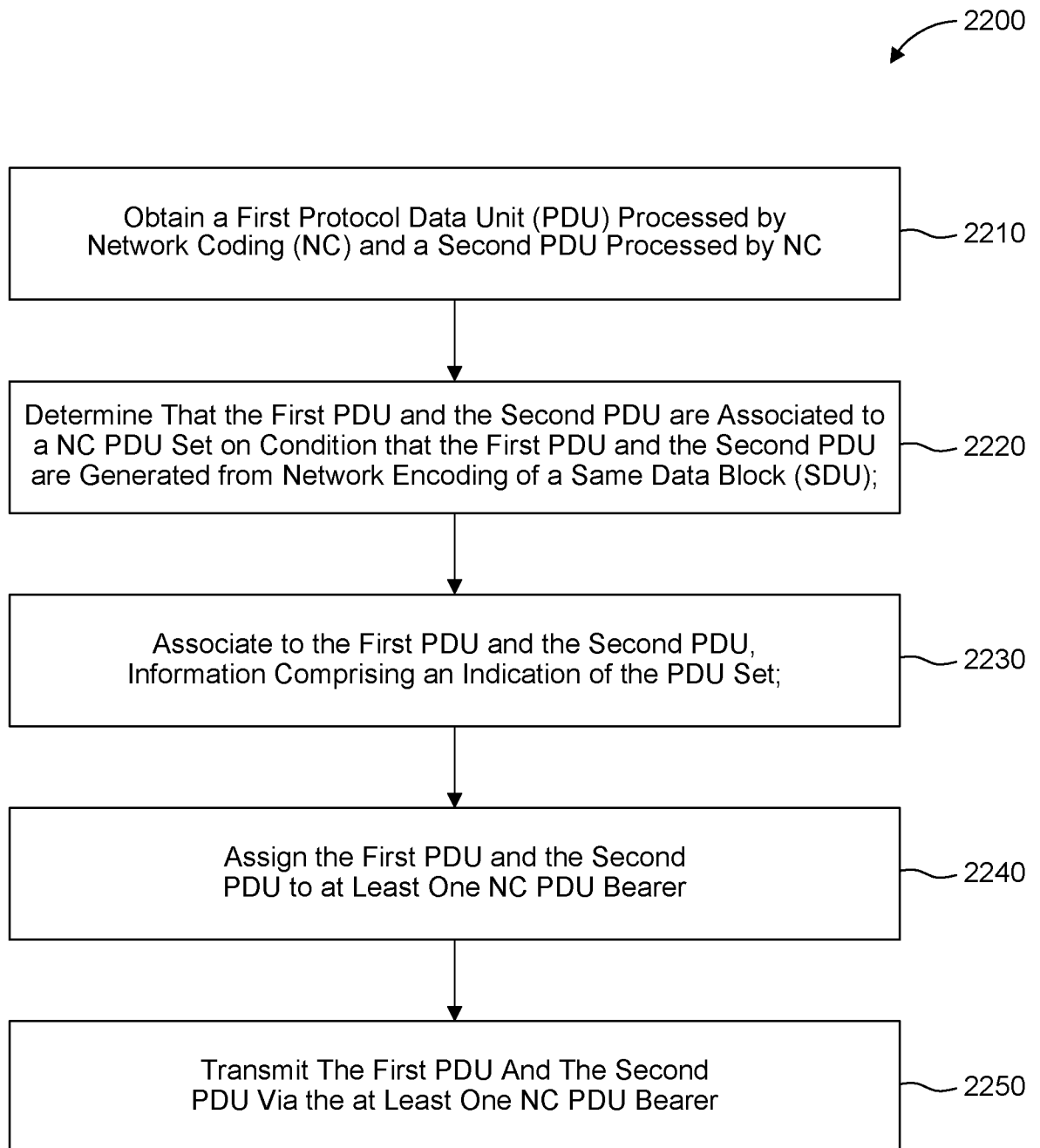


FIG. 22

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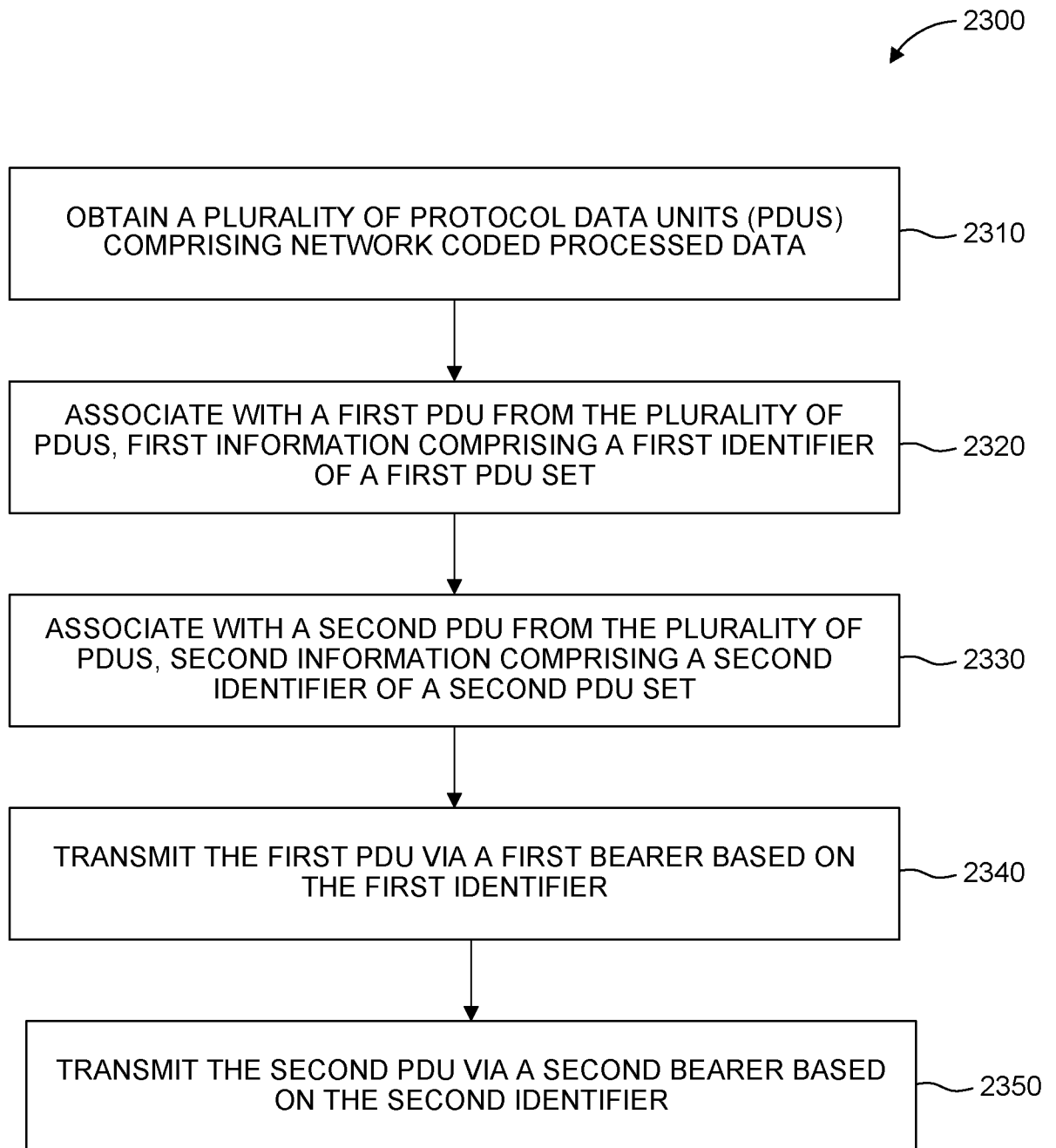


FIG. 23

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/033965

A. CLASSIFICATION OF SUBJECT MATTER INV. H04L1/00 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) H04L H04W		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021/233929 A1 (CANON KK [JP]; CANON EUROPE LTD [GB]) 25 November 2021 (2021-11-25) abstract page 18, line 23 - page 28, line 10 figures 5A, 5B, 6, 7, 8 -----	1 - 20
X	US 2022/173834 A1 (VIDAL GABRIEL ARROBO [US] ET AL) 2 June 2022 (2022-06-02) abstract paragraph [0200] - paragraph [0207] figures 12-14 -----	1 - 20
A	US 2021/120478 A1 (AKL NAEEM [US] ET AL) 22 April 2021 (2021-04-22) abstract paragraph [0088] - paragraph [0096] figure 9 ----- - / - -	1 - 20
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 24 September 2024		Date of mailing of the international search report 08/10/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Garrammone, Giuliano

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/033965

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"Universal Mobile Telecommunications System (UMTS); Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs (3GPP TS 26.346 version 6.2.0 Release 6)", TECHNICAL SPECIFICATION, EUROPEAN TELECOMMUNICATIONS STANDARDS INSTITUTE (ETSI), 650 ROUTE DES LUCIOLES, SOPHIA ANTIPOLIS CEDEX, F-06921, FRANCE, vol. 3-SA4, no. V6.2.0, 1 September 2005 (2005-09-01), XP014031961, * Annex B * -----	1 - 20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2024/033965

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		TW 202131666 A	16-08-2021
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