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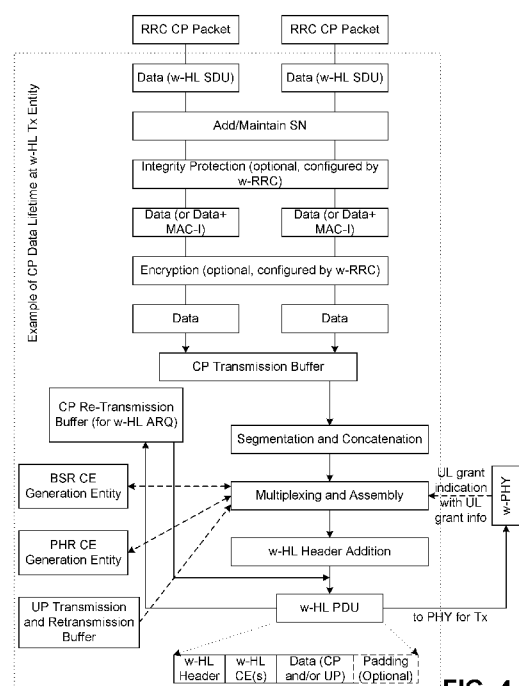


FIG. 4

(57) Abstract: Techniques for implementing a wearable higher layer (w-HL) for communications involving a wearable user equipment (wUE) are discussed. One example involves assigning a distinct sequence number to each of one or more control plane (CP) packets from a wearable radio resource control (w-RRC) layer; buffering the one or more CP packets to a CP transmission buffer; determining a physical resource assignment (PRA) and an allocated size for a wearable higher layer (w-HL) control protocol data unit (C-PDU); generating the w-HL C-PDU based at least in part on the one or more CP packets buffered to the CP transmission buffer, the PRA, and the allocated size; adding a packet header to the w-HL C-PDU; and providing the w-HL C-PDU to a physical layer based on the PRA.

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HIGHER LAYER DESIGN FOR CONTROL PLANE PACKET PROCESSING IN FIFTH GENERATION (5G)-WEARABLE COMMUNICATION

REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/338,917 filed May 19, 2016, entitled "HIGHER LAYER DESIGN FOR CONTROL PLANE PACKET PROCESSING IN 5G-WEARABLE COMMUNICATION", the contents of which are herein incorporated by reference in their entirety.

FIELD

[0002] The present disclosure relates to wireless technology, and more specifically to a higher layer design for communications between wearable user equipments (wUEs) and network UEs (nUEs).

BACKGROUND

[0003] Conventional LTE (Long Term Evolution) systems employ a higher layer protocol stack that encompasses the protocol layers between PHY (the physical layer) and the RRC (radio resource control) layer for control plane traffic or the IP (Internet protocol) or application layers for user plane traffic. In conventional LTE, these higher layer protocol layers are the MAC (medium access control), RLC (radio link control), and PDCP (packet data convergence protocol) layers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] **FIG. 1** is a block diagram illustrating an example user equipment (UE) useable in connection with various aspects described herein.

[0005] **FIG. 2** is an example diagram of a communication system that can facilitate fifth generation (5G) wearable (5G-Wearable or 5G-W) communications according to various aspects described herein.

[0006] **FIG. 3** is a diagram illustrating a protocol stack for a wUE (wearable UE)-nUE (network UE) interface, according to various aspects described herein.

[0007] **FIG. 4** is a flow diagram illustrating an example of processing details control plane (CP) data may go through at a w-HL (wearable higher layer) layer according to various aspects described herein.

[0008] **FIG. 5** is a block diagram illustrating a system that facilitates a higher layer for wearable communication (w-HL) at a UE, according to various aspects described herein.

[0009] **FIG. 6** is a flow diagram illustrating a method that facilitates generation of a w-HL C-PDU (control plane protocol data unit) from one or more w-RRC (wearable radio resource control) CP packets, according to various aspects described herein.

[0010] **FIG. 7** is a flow diagram illustrating a method that facilitates generation and in-order delivery of one or more w-RRC CP packets from one or more received TBs (transport blocks), according to various aspects described herein.

[0011] **FIG. 8A** is a diagram illustrating an example of a padding subheader that can be added at the beginning of a w-HL C-PDU header when a left over grant has only one Byte to exactly match a w-HL C-PDU size to the grant size, according to various aspects described herein.

[0012] **FIG. 8B** is a diagram illustrating an example of a padding subheader that can be added at the beginning of a w-HL C-PDU header when a left over grant has only two Bytes to exactly match the w-HL C-PDU size to the grant size, according to various aspects described herein.

[0013] **FIG. 8C** is a diagram illustrating an example of a padding subheader that can be added at the end of a w-HL C-PDU header to enable insertion of 0 or more Bytes of padding data field at the end of a w-HL-PDU (data field) so that the w-HL C-PDU size can be matched exactly to the grant size, according to various aspects described herein.

[0014] **FIG. 9A** is a diagram illustrating an example of a C-PDU consisting of only a CP SDU (service data unit) from UL (uplink) CP Transmission buffer.

[0015] **FIG. 9B** is a diagram illustrating an example of a C-PDU consisting of a BSR (buffer status report) and a CP SDU from UL CP Transmission buffer.

[0016] **FIG. 10A** is a diagram illustrating an example of a C-PDU consisting of a PHR (power headroom report) and a CP SDU from UL CP Transmission buffer.

[0017] **FIG. 10B** is a diagram illustrating an example of a C-PDU consisting of a BSR, a PHR and a CP SDU from UL CP Transmission buffer.

[0018] **FIG. 11** is a diagram illustrating an example of a C-PDU similar to that in FIG. 10B, with one byte of padding subheader at the beginning.

[0019] **FIG. 12** is a diagram illustrating an example of a C-PDU similar to that in FIG. 10B, with two bytes of padding subheader at the beginning.

[0020] **FIG. 13** is a diagram illustrating an example of a C-PDU similar to that in FIG. 10B, with bytes of padding subheader at the end.

[0021] **FIG. 14** is a diagram illustrating an example a w-HL C-PDU having a BSR, a PHR, and a CP-SDU segment (that is not the last segment of this SDU) from a UL CP Tx (transmission) buffer.

[0022] **FIG. 15** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR and a CP-SDU segment (that is the last segment of this SDU) from the UL CP TX buffer.

[0023] **FIG. 16A** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU (user plane SDU) from UL User plane Tx buffer.

[0024] **FIG. 16B** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU segment (not last segment of this SDU) from UL user plane TX buffer.

[0025] **FIG. 17A** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU segment (last segment of this SDU) from UL user plane TX buffer.

[0026] **FIG. 17B** is a diagram illustrating an example of an ARQ retransmission of a w-HL C-PDU having a BSR, a PHR and a C-PDU (not resegmented) from UL ARQ control plane retransmission buffer.

[0027] **FIG. 18A** is a diagram illustrating an example of an ARQ retransmission of a w-HL C-PDU having a BSR, a PHR and a C-PDU segment (not last segment of this resegmented C-PDU) from UL ARQ control plane retransmission buffer.

[0028] **FIG. 18B** is a diagram illustrating an example of an ARQ retransmission of a w-HL C-PDU segment having a BSR, a PHR and a C-PDU Segment (last segment of this resegmented C-PDU) from UL ARQ control plane retransmission buffer.

[0029] **FIG. 19** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a CP-SDU from UL control plane TX buffer and an UP-SDU from UL user plane TX buffer.

[0030] **FIG. 20** is a diagram illustrating an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU from UL control plane TX buffer and an UP-SDU segment (not last segment of the UP-SDU) from UL user plane TX buffer.

[0031] **FIG. 21** is a diagram illustrating an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU segment (last segment of this SDU) from UL control plane TX buffer and an UP-SDU from UL user plane TX buffer.

[0032] **FIG. 22** is a diagram illustrating an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU segment (last segment of this SDU) from UL control plane TX buffer, and a UP-SDU Segment (not last segment of this SDU) from UL user plane TX buffer.

[0033] **FIG. 23** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer and a UP-SDU from UL user plane TX buffer.

[0034] **FIG. 24** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer and a UP-SDU segment (not last segment) from UL user plane TX buffer.

[0035] **FIG. 25** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer, a CP SDU from UL control plane transmission buffer and a UP-SDU (not segmented) from UL user plane TX buffer.

[0036] **FIG. 26** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU Segment (Last Segment of this resegmented C-PDU) from UL control plane retransmission buffer and a CP-SDU from UL Control plane TX buffer.

[0037] **FIG. 27** is a diagram illustrating an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU Segment (Last Segment of this resegmented C-PDU) from UL control plane retransmission buffer and a CP-SDU Segment (Not last Segment) from UL Control plane TX buffer.

DETAILED DESCRIPTION

[0038] The present disclosure will now be described with reference to the attached drawing figures, wherein like reference numerals are used to refer to like elements throughout, and wherein the illustrated structures and devices are not necessarily drawn to scale. As utilized herein, terms “component,” “system,” “interface,” and the like are intended to refer to a computer-related entity, hardware, software (e.g., in execution), and/or firmware. For example, a component can be a processor (e.g., a microprocessor, a controller, or other processing device), a process running on a processor, a controller, an object, an executable, a program, a storage device, a computer, a tablet PC and/or a user equipment (e.g., mobile phone, etc.) with a processing device. By way of illustration, an application running on a server and the server can also be a component. One or more components can reside within a process, and a component can be localized on one computer and/or distributed between two or more computers. A set of

elements or a set of other components can be described herein, in which the term “set” can be interpreted as “one or more.”

[0039] Further, these components can execute from various computer readable storage media having various data structures stored thereon such as with a module, for example. The components can communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network, such as, the Internet, a local area network, a wide area network, or similar network with other systems via the signal).

[0040] As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry, in which the electric or electronic circuitry can be operated by a software application or a firmware application executed by one or more processors. The one or more processors can be internal or external to the apparatus and can execute at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts; the electronic components can include one or more processors therein to execute software and/or firmware that confer(s), at least in part, the functionality of the electronic components.

[0041] Use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or”. That is, unless specified otherwise, or clear from context, “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then “X employs A or B” is satisfied under any of the foregoing instances. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from context to be directed to a singular form. Furthermore, to the extent that the terms “including”, “includes”, “having”, “has”, “with”, or variants thereof are used in either the detailed description and the claims, such terms are intended to be inclusive in a manner similar to the term “comprising.”

[0042] As used herein, the term “circuitry” may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit,

and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

[0043] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. **FIG. 1** illustrates, for one embodiment, example components of a User Equipment (UE) device 100. In some embodiments, the UE device 100 may include application circuitry 102, baseband circuitry 104, Radio Frequency (RF) circuitry 106, front-end module (FEM) circuitry 108 and one or more antennas 110, coupled together at least as shown.

[0044] The application circuitry 102 may include one or more application processors. For example, the application circuitry 102 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0045] The baseband circuitry 104 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 104 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 106 and to generate baseband signals for a transmit signal path of the RF circuitry 106. Baseband processing circuitry 104 may interface with the application circuitry 102 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 106. For example, in some embodiments, the baseband circuitry 104 may include a second generation (2G) baseband processor 104a, third generation (3G) baseband processor 104b, fourth generation (4G) baseband processor 104c, and/or other baseband processor(s) 104d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 104 (e.g., one or more of baseband processors 104a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 106. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 104

may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 104 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

[0046] In some embodiments, the baseband circuitry 104 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 104e of the baseband circuitry 104 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 104f. The audio DSP(s) 104f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 104 and the application circuitry 102 may be implemented together such as, for example, on a system on a chip (SOC).

[0047] In some embodiments, the baseband circuitry 104 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 104 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 104 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0048] RF circuitry 106 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 106 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 106 may include a receive signal path which may include circuitry to down-convert RF signals received

from the FEM circuitry 108 and provide baseband signals to the baseband circuitry 104. RF circuitry 106 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 104 and provide RF output signals to the FEM circuitry 108 for transmission.

[0049] In some embodiments, the RF circuitry 106 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 106 may include mixer circuitry 106a, amplifier circuitry 106b and filter circuitry 106c. The transmit signal path of the RF circuitry 106 may include filter circuitry 106c and mixer circuitry 106a. RF circuitry 106 may also include synthesizer circuitry 106d for synthesizing a frequency for use by the mixer circuitry 106a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 106a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 108 based on the synthesized frequency provided by synthesizer circuitry 106d. The amplifier circuitry 106b may be configured to amplify the down-converted signals and the filter circuitry 106c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 104 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 106a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0050] In some embodiments, the mixer circuitry 106a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 106d to generate RF output signals for the FEM circuitry 108. The baseband signals may be provided by the baseband circuitry 104 and may be filtered by filter circuitry 106c. The filter circuitry 106c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0051] In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a may be

arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 106a of the receive signal path and the mixer circuitry 106a of the transmit signal path may be configured for super-heterodyne operation.

[0052] In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 106 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 104 may include a digital baseband interface to communicate with the RF circuitry 106.

[0053] In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0054] In some embodiments, the synthesizer circuitry 106d may be a fractional-N synthesizer or a fractional $N/N+1$ synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 106d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0055] The synthesizer circuitry 106d may be configured to synthesize an output frequency for use by the mixer circuitry 106a of the RF circuitry 106 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 106d may be a fractional $N/N+1$ synthesizer.

[0056] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 104 or the applications processor 102 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 102.

[0057] Synthesizer circuitry 106d of the RF circuitry 106 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or $N+1$ (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-

flop. In these embodiments, the delay elements may be configured to break a VCO period up into N_d equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0058] In some embodiments, synthesizer circuitry 106d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (f_{LO}). In some embodiments, the RF circuitry 106 may include an IQ/polar converter.

[0059] FEM circuitry 108 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 110, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 106 for further processing. FEM circuitry 108 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 106 for transmission by one or more of the one or more antennas 110.

[0060] In some embodiments, the FEM circuitry 108 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 106). The transmit signal path of the FEM circuitry 108 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 106), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 110).

[0061] In some embodiments, the UE device 100 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0062] Additionally, although the above example discussion of device 100 is in the context of a UE device (e.g., a wearable UE (wUE) or a network UE (nUE)), in various aspects, a similar device can be employed in connection with a base station (BS) such as an Evolved NodeB (eNB), etc.

[0063] In various aspects, techniques disclosed herein can employ a simplified higher layer design for communication between a wUE and a nUE, involving a single layer (referred to herein as wearable higher layer (w-HL)) between the w-RRC (wearable radio resource control) layer and PHY (the physical layer) for the control plane, or between the IP/application layers and PHY for the user plane.

[0064] Referring to **FIG. 2**, illustrated is an example diagram of a communication system 200 that can facilitate fifth generation (5G) wearable (5G-Wearable or 5G-W) communications according to various aspects described herein. The communication system of FIG. 2 shows the following network nodes and interfaces: (1) a nUE (network UE) with a full infrastructure network (NW) access protocol stack (e.g., full C/U (control/user) plane functions); (2) three wUEs (wearable UEs), one with a direct NW connection and two accessing the NW (e.g., the E-UTRAN (Evolved Universal Terrestrial Radio Access Network) and EPC (Evolved Packet Core), etc.) only via the assistance of the nUE (one of which accessing also via another of the wUEs); (3) a PAN (personal area network) comprising the nUE and the wUEs, which can employ mutual authentication to form the PAN; (4) the Uu-p interface, the air interface between the NW and the nUE; (5) the Uu-w interface, the air interface between the NW and the wUE; (6) the Xu-a interface, the intra-PAN air interface between the nUE and the wUE; and (7) the Xu-b interface, the intra-PAN air interface among wUEs.

[0065] Various embodiments discussed herein relate to the Xu-a interface shown in FIG. 2. In various situations, a wUE can communicate with the E-UTRAN via the nUE. Each nUE can have several wUEs associated with it which together form a PAN (such as the nUE and three wUEs shown in FIG. 2). In general, there can be a large number of nUEs in a geographical region, each of which can have its own PAN, which can create a highly dense network scenario. The E-UTRAN can assign a common resource pool for wearable communication. This resource pool can be shared among multiple PANs in a relatively small geographical area, and among potentially multiple wUEs within each PAN on a contention based resource access basis. Each nUE can have two higher layer protocol stacks: one for the interface between wUE and nUE (the Xu-a air interface) and one for the interface between nUE and E-UTRAN (the Uu-p air interface). The Higher Layer protocol stack for the interface nUE-EUTRAN can be the LTE Uu stack or can be an LTE evolved 5G protocol stack. The higher layer protocol stack can refer mainly to the protocol layer(s) in between PHY and the Radio Resource Control layer for control plane traffic and between PHY and the IP/Application layers for user

plane traffic. As one specific example, higher layer refer to the MAC, RLC and PDCP layers in conventional LTE systems.

[0066] Due to the contention environment for communication over the Xu-a interface, each packet transmission (e.g., PHY transport block (TB) size) can be shorter in wearable communication in order to reduce the impact of collision on system performance. In one example, the TB size can be a relatively small number of bytes, such as less than 75 bytes. In such a use case, reducing the size of packet header added at the higher layer can ensure that the data-to-packet-header ratio remains reasonable. The higher layer protocol design and packet processing procedure design for higher layer discussed herein can minimize the higher layer protocol header overhead per packet transmission, which can increase throughput. In various embodiments, a single wearable higher layer (w-HL) can be employed for the control plane, which can provide some or all of the following features: (1) a simplified Higher layer protocol design; (2) functionalities of a Higher layer protocol customized for wearable communication; (3) a reduced number of protocol layer specific header fields (e.g., addition of multiple levels of packet ID (such as sequence number) is avoided); (4) a shorter size of various packet header fields; (5) packet segmentation and combination with lower packet header overhead; (6) multiplexing of buffer status report (BSR), power headroom report (PHR), control plane data and user plane data; and (7) retransmission of packets with lower packet header overhead.

[0067] In various aspects discussed herein, all of the higher layer functionalities (such as conventional LTE MAC/RLC/PDCP functionalities) for control plane data processing can be merged into a single layer referred to herein as Wearable Higher Layer (w-HL), which can reduce packet header during transmission over the air-interface. The packet header reduction can provide significant advantages in terms of throughput, given that the fact that each PHY-SDU (PHY service data unit, e.g., PHY TB) on the control PRA (physical resource assignment) can be of very small size (e.g., 180-600 bits or 22.5-75 bytes) for the 5G-w, in contrast to conventional LTE.

[0068] Referring to **FIG. 3**, illustrated is a protocol stack for a wUE-nUE interface (e.g., the Xu-a interface discussed herein), according to various aspects described herein. For the UL (uplink) transmission, a CP/UP (control plane/user plane) data packet to be transmitted over the air-interface can be received as a w-HL service data unit (w-HL SDU) from the wearable-RRC (control plane data) layer or IP/host (user plane data) layer. The w-RRC layer can handle the configuration of the w-HL. The w-HL can store the CP data in a UL CP transmission buffer until PHY indicates a UL grant on

a control PRA. The w-HL can store the UP data in a UL UP transmission buffer. Various aspects described herein relate to techniques associated with CP data processing. The w-HL can form a CP w-HL protocol data unit (CP w-HL PDU), which can be based on the TB size indicated by PHY. The w-HL can then pass the w-HL CP PDU to PHY for transmission. The CP data packet w-HL SDU can go through several operations discussed herein during its lifetime in the w-HL protocol layer.

[0069] Referring to **FIG. 4**, illustrated is an example flow diagram showing processing details control plane (CP) data may go through at a w-HL layer according to various aspects described herein. FIG. 4 also shows generation of a PDU to be transmitted on a control PRA/resource (such a PDU is referred to herein as a control PDU or C-PDU). Some of the functionalities of w-HL for control plane data include: (1) maintenance of w-HL SNs (sequence numbers); (2) optional (e.g., configured by w-RRC) integrity protection of control plane data flows; (3) optional (e.g., configured by w-RRC) ciphering and deciphering of control plane data; (4) in-sequence delivery of upper layer data; (5) duplicate detection and discarding of duplicate w-HL CP SDU(s); (6) w-HL CP SDU discard (e.g., timer based); (7) concatenation, segmentation and reassembly of SDUs; (8) multiplexing buffer status report, power headroom report, control plane data and/or user plane data; (9) re-segmentation of w-HL C-PDUs; and (10) protocol error detection and recovery by retransmission at two levels: (a) HARQ (hybrid ARQ (automatic repeat request)) first at the TB level and (b) ARQ (automatic repeat request) at the w-HL C-PDU level.

[0070] In various embodiments discussed herein, a w-HL can be employed that was based on the following design choices for guiding CP data processing at w-HL. First, an implicitly/explicitly known separate PRA/resource (referred to herein as control PRA) can be employed for the transmission of control plane data. In various aspects, control plane data is transmitted solely on the control PRA, and other PRAs can be employed for user plane data transmission. A PRA (Physical resource Assignment) is the basic unit of physical resource allocation of a resource block. Second, the power headroom report (PHR) and buffer status report (BSR) can be piggybacked in a w-HL PDU transmitted on control PRA. Third, if there is grant resource left after placing BSR, PHR, and/or CP data, User plane data (e.g., UP data pending for transmission in UL UP Tx (transmission) buffer or UL UP retransmission buffer) can be included in the w-HL C-PDU for control PRA. Therefore, a multiplexing and assembly operation for w-HL PDU for control PRA can be employed in various embodiments.

[0071] Referring to **FIG. 5**, illustrated is a block diagram of a system 500 that facilitates a higher layer for wearable communication (w-HL) at a UE (e.g., network UE (nUE) or wearable UE (wUE)), according to various aspects described herein. System 500 can include one or more processors 510 (e.g., one or more baseband processors such as one or more of the baseband processors discussed in connection with FIG. 1), transceiver circuitry 520 (e.g., comprising one or more of transmitter circuitry or receiver circuitry, which can employ common circuit elements, distinct circuit elements, or a combination thereof), and a memory 530 (which can comprise any of a variety of storage mediums and can store instructions and/or data associated with one or more of processor(s) 510 or transceiver circuitry 520). In various aspects, system 500 can be included within a user equipment (UE), either in a wearable UE (wUE) or in a network UE (nUE). As described in greater detail below, system 500 can provide higher layer functionality for control messaging between a network UE (nUE) and one or more wearable UEs (wUEs) within a personal area network (PAN).

[0072] Processor(s) 510 can implement a wearable higher layer (w-HL) that can perform higher layer functionalities associated with control messaging exchanged between a wUE and a nUE. In embodiments discussed herein, such higher layer functionality (e.g., functionality of layer(s) between the w-RRC (wearable radio resource control) layer and PHY (the physical layer)) can be implemented by processor(s) 510 via a single layer, referred to herein as w-HL (wearable higher layer), in contrast to conventional LTE systems, which employ three layers (MAC, RLC, and PDCP). In various aspects, processor(s) 510 can implement functions associated with a w-HL transmission (Tx) entity and/or functions associated with a w-HL reception (Rx) entity.

[0073] In w-HL Tx aspects, processor(s) 510 can implement one or more functions associated with a w-HL Tx entity, such as any of the acts shown or described in connection with FIG. 4. For example, processor(s) 510 can receive one or more w-RRC (radio resource control) CP (control plane) packets as w-HL SDU (service data unit) packets. Processor(s) 510 can assign a distinct sequence number (SN) to the w-HL SDU(s). Optionally, processor(s) 510 can apply integrity protection and/or encryption (ciphering) to the w-HL SDU(s). Processor(s) 510 can add the w-HL SDU(s) (e.g., w-RRC CP packets) to a CP transmission buffer (e.g., an uplink (UL) CP Tx buffer at a wUE, a downlink (DL) CP Tx buffer at a nUE).

[0074] Processor(s) 510 can determine a physical resource assignment (PRA) and corresponding allocation size for transmission of a w-HL PDU (protocol data unit) via

PHY (the physical layer) by transceiver circuitry 520. In wUE aspects, the PRA can be indicated via an UL grant (e.g., from the nUE).

[0075] Based on the PRA and allocated size, processor(s) 510 can generate a w-HL PDU, which can comprise one or more of a buffer status report (BSR) (e.g., when processor(s) 510 determine to include the BSR), a power headroom report (PHR) (e.g., when processor(s) 510 determine to include the PHR), one or more w-HL SDUs or segments thereof from the CP Tx buffer (e.g., wherein processor(s) 510 can perform segmentation as appropriate based on the allocated size), one or more w-HL PDUs or segments thereof from a CP retransmission buffer (e.g., wherein processor(s) 510 can perform re-segmentation as appropriate based on the allocated size), and/or user plane (UP) data from a UP Tx buffer and/or a UP retransmission buffer. Each of the BSR, PHR, CP retransmission buffer, CP Tx buffer, UP retransmission buffer, and UP Tx buffer can have an associated priority, which in some aspects can be prioritized in that order (BSR, PHR, CP retransmission buffer, CP Tx buffer, etc.). Processor(s) 510 can include the BSR and/or PHR based on a determination by processor(s) 510 to include the BSR/PHR (e.g., receiving a trigger/request to provide BSR/PHR, based on current BSR/PHR status, etc.). For an allocation size sufficient to multiplex multiple items in the w-HL C-PDU, processor(s) 510 can perform such multiplexing based on the associated priorities. In some aspects, processor(s) 510 can add padding to the w-HL C-PDU to match the size of the w-HL C-PDU to the allocation size.

[0076] Processor(s) 510 can add a w-HL packet header to the w-HL C-PDU generated as described herein, which, depending on the data content of the w-HL C-PDU, can comprise one or more sub-headers indicating the contents of the w-HL C-PDU.

[0077] Processor(s) 510 can pass the w-HL C-PDU with header to PHY for transmission by transceiver circuitry 520 via the PRA.

[0078] Processor(s) 510 can employ a two-level retransmission mechanism in connection with the w-HL C-PDU(s).

[0079] Processor(s) 510 can employ a HARQ (Hybrid Automatic Repeat reQuest) mechanism at the physical layer TB level, which can involve processor(s) 510 processing HARQ ACK feedback (e.g., ACK (acknowledgement) or NACK (negative acknowledgement)) received via transceiver circuitry 520 in response to TBs used to communicate the w-HL C-PDU via PHY. In response to NACK(s), processor(s) 510 can retransmit the TB(s) one or more times unless a HARQ retransmission limit has been reached.

[0080] Processor(s) 510 can also employ an ARQ (Automatic Repeat reQuest) mechanism at the w-HL C-PDU level, which can involve processor(s) 510 processing ARQ ACK feedback (e.g., ACK (acknowledgement) or NACK (negative acknowledgement)) received via transceiver circuitry 520 in response to w-HL C-PDU(s) via PHY. In response to NACK(s), processor(s) 510 can pass the w-HL C-PDU to PHY for retransmission one or more times (e.g., which can involve re-segmentation, etc.) unless an ARQ retransmission limit has been reached. In processing the w-HL C-PDU to be passed to PHY again, processor(s) 510 can re-determine a PRA and allocated size for the w-HL C-PDU (e.g., based on a new UL grant, etc.). Depending on the allocated size for the w-HL C-PDU, this can involve processor(s) 510 multiplexing the CP data of the w-HL C-PDU with other data (e.g., BSR, PHR, other CP data or segments thereof, UP data, etc.) and/or processor(s) 510 re-segmenting the w-HL C-PDU.

[0081] In w-HL Rx aspects, processor(s) 510 can implement one or more functions associated with a w-HL Rx entity (e.g., at a nUE or a wUE). For example, processor(s) 510 can generate HARQ ACK feedback (e.g., ACK/NACK, etc.) that can be transmitted by transceiver circuitry 520 in response to TB(s) successfully or unsuccessfully received by transceiver circuitry 520 in connection with one or more w-HL C-PDUs. Processor(s) 510 can generate the w-HL C-PDU(s) based on the TB(s) received by transceiver circuitry 520. Processor(s) 510 can also generate ARQ ACK feedback (e.g., ACK/NACK, etc.) that can be transmitted by transceiver circuitry 520 in response to w-HL C-PDU(s) successfully or unsuccessfully reconstructed by processor(s) 510. In nUE aspects, processor(s) 510 can generate (and transceiver circuitry 520 can transmit) UL grant(s) that indicate PRA(s) and allocated size(s) that the w-HL C-PDU(s) are received via.

[0082] Processor(s) 510 can provide the generated w-HL C-PDU(s) from PHY to w-HL for higher layer processing by processor(s) 510. As discussed herein, individual w-HL C-PDU(s) can comprise one or more of a BSR, a PHR, one or more CP packets and/or segments thereof, or one or more UP packets and/or segments thereof. For w-HL C-PDU(s) that comprise a multiplexing of two or more data, the header(s) of the w-HL C-PDU(s) can comprise two or more subheaders, which can indicate information associated with the two or more data.

[0083] From the w-HL C-PDU(s), processor(s) 510 can generate one or more w-HL C-SDUs (e.g., w-RRC CP packet(s)). From the header(s) of the w-HL C-PDU(s) and SN(s) indicated therein, processor(s) 510 can determine an ordering of the C-SDU(s)

(RRC CP packet(s)) and deliver the C-SDU(s) (w-RRC CP packet(s)) in order to a w-RRC layer.

[0084] Referring to **FIG. 6**, illustrated is a flow diagram of a method 600 that facilitates generation of a w-HL C-PDU from one or more w-RRC CP packets, according to various aspects described herein. In some aspects, method 600 can be performed at a UE. In other aspects, a machine readable medium can store instructions associated with method 600 that, when executed, can cause a UE (e.g., nUE or wUE) to perform the acts of method 600.

[0085] At 610, one or more w-HL C-SDUs can be received from a w-RRC layer.

[0086] At 620, a unique SN can be assigned to each of the one or more w-HL C-SDUs.

[0087] At 630, the one or more w-HL C-SDUs can be stored in a UL CP Tx buffer.

[0088] At 640, one or more PRAs and allocated sizes can be determined for transmission of the one or more w-HL C-PDUs.

[0089] At 650, one or more w-HL C-PDUs can be generated based at least in part on the PRA and allocated size. The w-HL C-PDU(s) can comprise one or more of BSR, PHR, UL CP Tx buffer, UL CP retransmission buffer, UL UP Tx buffer, or UL UP retransmission buffer.

[0090] At 660, the w-HL C-PDU can be passed to PHY.

[0091] At 670, the w-HL C-PDU can be transmitted via one or more TBs.

[0092] Additionally or alternatively, method 600 can include one or more other acts performed by a w-HL Tx entity described above in connection with system 500.

[0093] Referring to **FIG. 7**, illustrated is a flow diagram of a method 700 that facilitates generation and in-order delivery of one or more w-RRC CP packets from one or more received TBs, according to various aspects described herein. In some aspects, method 700 can be performed at a UE. In other aspects, a machine readable medium can store instructions associated with method 700 that, when executed, can cause a UE (e.g., nUE or wUE) to perform the acts of method 700.

[0094] At 710, one or more TBs can be received carrying w-RRC CP packet data.

[0095] At 720, one or more w-HL C-PDUs can be generated from the one or more TBs.

[0096] At 730, the one or more w-HL C-PDUs can be passed to a w-HL for further processing.

[0097] At 740, one or more w-HL C-SDUs (e.g., w-RRC CP packet(s)) can be generated from the one or more w-HL C-PDUs.

[0098] At 750, based on a SN of a header of each of the one or more w-HL C-PDUs, an ordering of the one or more w-HL C-SDUs can be determined.

[0099] At 760, the one or more w-HL C-SDUs can be delivered in order to the w-RRC layer.

[00100] Additionally or alternatively, method 700 can include one or more other acts performed by a w-HL Rx entity described above in connection with system 500.

Control Plane Packet Processing at w-HL:

[00101] The following details can be employed for packet processing and header additions for control plane data in connection with a w-HL as described herein.

[00102] When w-HL receives a packet from a higher layer (w-RRC), the packet becomes a CP w-HL SDU (service data unit) for w-HL protocol layer.

[00103] A sequence number (SN) can be added per w-HL CP SDU (to save header overhead, a SN per w-HL C-PDU can be omitted). Encryption (ciphering/deciphering) and/or Integrity protection can be done per CP SDU, and a SDU SN can be used for these operations, thus a sequence number (SN) can be added per w-HL SDU.

[00104] CP SDUs can be stored in a separate buffer than the UP SDUs. Therefore, the sequence number assignment can be independent for CP and UP. That is, a SN does not need to be unique among CP and UP SDUs. However, a CP SDU SN can be unique among SNs assigned to CP SDUs to avoid errors. Additionally, the SN for a CP SDU does not need to be of the same length as that for a UP SDU.

[00105] If Integrity protection is enabled by w-RRC, w-HL can perform an Integrity protection operation on CP SDU. Otherwise, the w-HL CP SDU can skip the Integrity protection operation. The Integrity protection operation increases the size of the w-HL SDU by adding some integrity check bytes.

[00106] If encryption is enabled, the w-HL CP SDU can go through a ciphering operation which adds security to the air-interface transmission. Ciphering does not change the size of the w-HL CP SDU.

[00107] The w-HL CP SDU (possibly modified CP SDU if Integrity protection and/or Encryption operations were performed) can be placed in UL CP Transmission buffer along with its assigned SN. Note that the w-HL header can be added when the w-HL C-PDU is generated upon request from PHY layer. PHY can ask for the w-HL PDU if there is an UL grant received on control PRA, in aspects employed at a wUE.

[00108] Buffering of the w-HL SDU in the UL CP transmission buffer can trigger sending a scheduling request to the nUE in order to request an UL grant on control PRA, in aspects employed at a wUE.

[00109] Once an UL grant is received at PHY for transmission on control PRA, PHY can pass the UL grant to w-HL, asking to provide a w-HL C-PDU for transmission on control PRA. A w-HL C-PDU can then be generated with size made equal to the PHY transport block (TB) size (e.g., size of a received UL grant).

[00110] w-HL can generate a w-HL C-PDU, which can involve multiplexing BSR, PHR, w-HL CP SDUs buffered in UL CP Tx buffer (and/or UL CP ARQ retransmission buffer), and w-HL UP SDUs buffered in UL UP Tx buffer (and/or UL UP ARQ retransmission buffer). Based on the grant size, w-HL can do one or more of the following: segment an SDU from UL CP/UP Tx buffer; re-segment a w-HL CP/UP PDU from UL CP/UP ARQ retransmission buffer; combine one or more SDU segments; combine 1 or more SDUs; and/or combine 0 or 1 BSR, 0 or 1 PHR, 0 or more re-segments, 0 or more CP/UP segments and 0 or more CP/UP SDUs.

[00111] The w-HL can then add a packet header to create a w-HL C-PDU for the control PRA. As used herein, the w-HL PDU for the control PRA can also be referred to as a w-HL C-PDU or a w-HL CP PDU. Examples of packet header additions and their details are discussed in greater detail below. w-HL can store a copy of the w-HL C-PDU in the UL CP ARQ retransmission buffer. w-HL can pass the w-HL C-PDU to PHY for transmission on control PRA.

[00112] PHY can transmit the w-HL C-PDU one or more times, until either (a) the w-HL C-PDU is received successfully at the nUE/wUE or (b) a maximum HARQ retransmissions limit is reached.

[00113] If the intended recipient (nUE/wUE) is unable to successfully receive the w-HL C-PDU in a maximum number of HARQ retransmission tries, w-HL can invoke an ARQ retransmission procedure.

[00114] During ARQ retransmission, the original w-HL C-PDU can be re-segmented if the grant size is smaller, or it can be combined with other segment(s)/SDU(s) if the grant size is larger.

[00115] For each ARQ retransmission, PHY can try up to the maximum number of HARQ retransmission times to deliver the C-PDU.

[00116] After a maximum number of ARQ retransmission tries, if a C-PDU failed to be successfully received at the nUE/wUE, w-HL can discard the associated SDU(s) and can inform a higher layer (protocol layer above w-HL, e.g., w-RRC) about it.

[00117] Below are details of packet header addition that can be employed at the w-HL layer while creating the w-HL PDU.

Higher Layer (w-HL) packet Header Design and Optimization for Control plane data:

Packet header design features at w-HL for control plane:

[00118] In connection with w-HL UP data, a sequence number (SN) of 10 bits can be assigned per w-HL SDU for the UP data such as IP data. A 10 bit SN can accommodate 1024 UP SDUs in the UL UP Tx buffer.

[00119] CP SDUs are generated by w-RRC. It is highly unlikely that there will be more than 128 w-RRC messages or control plane messages (i.e., w-HL CP SDUs) pending for transmission in the UL CP Tx buffer at any time. Thus, to reduce packet header size, in aspects, a control plane sequence number (C-SN) of 7 bits can be assigned to a CP SDU. Also, addition of a SN per w-HL C-PDU can be omitted, in order to reduce packet header overhead. Usually encryption and/or Integrity protection (when performed) are done per CP SDU and a CP SDU SN is used for this operation, thus a control sequence number (C-SN) can be added per w-HL CP SDU.

[00120] If retransmission is employed at the w-HL level (such as if w-HL ARQ is enabled), it can be done per w-HL C-PDU. In the absence of a SN per w-HL PDU, a tag (unique ID) as described herein can be employed to identify each C-PDUs so that w-HL Rx (Receive) entity can send the C-PDU Identification tag (unique ID) to the w-HL Tx (Transmit) entity while requesting a retransmission of missing C-PDU. For each case of w-HL C-PDU discussed below, tags are provided which can be used to identify each C-PDU. Usually a SDU C-SN (or SN) or a SDU C-SN (or SN) plus a Segment ID can be used as tag/ID to uniquely identify any w-HL C-PDU as described below.

[00121] As mentioned earlier, L1/PHY transport block can be limited to a few tens of Bytes (less than 75 Bytes) due to the contention based transmission environment over Xu-a interface. A smaller L1 TB size can be helpful in reducing the performance impact from potential collision. Table 1 below shows an example L1/PHY TB size range. In the example of table 1, the maximum C-PDU (or UP PDU) size is approximately 600 bits (75 Bytes) and the minimum is 176 bits (22 Bytes). The example of table 1 is used in the following discussion, although other sizes can be employed, with corresponding changes in various details.

Table 1: An example showing TB Size range for 5G-W.

	TB Sizes (bits)	TB Sizes (Bytes)
Min.	176	22
Max.	600	75

[00122] Length Indicator (LI): To represent a length (in Bytes) up to 75 Bytes, a Length Indicator (LI) = 7 bits can be employed. Seven bits are sufficient to specify a length up to 127 ($2^7 - 1$) Bytes.

[00123] Number of bits to represent Segment of a SDU: The number of bits to represent a segment of a CP SDU depends on the maximum size of SDU that can be received at the w-HL. The max supported PDCP SDU size in conventional LTE (Bytes) = 8188 Bytes. However, most of the control message packet size is much smaller than 8188 Bytes in wearable communication. In general, the control plane message size will be ≤ 1500 Bytes. Based on these possible two maximum SDU sizes, a segment ID can be designed. For user plane data sizes, both options of maximum packet sizes, 8188 Bytes and 1500 Bytes, can be assumed.

[00124] There are two ways to represent a segment: (i) specify Start/End Byte within SDU for the segment, which can be specified via 13 bits (for a maximum SDU Size = 8188 Byte) or 11 bits (for a maximum SDU Size = 1500 Byte), and/or (ii) specify a Segment number, which can be specified via 9 bits (for a maximum segment # = $8188/22 = 373$) or 7 bits (for a maximum segment # = $1500/22 = 69$). Thus, it is more efficient to specify segment Number as a segment id, as Segment Number uses a lower number of bits. However, this can add some processing complexity at w-HL layer for the Transmit side/entity. w-HL layer Transmit side/entity can remember Segment start/end bytes locally for each segment.

[00125] Higher Priority for Retransmission: Re-transmission data can have a higher priority than new transmission. Thus, Re-segmented data can be the first data segment/field if an UL grant is available in a TTI (transmission time interval) expecting HARQ/ARQ retransmission.

[00126] Separation of PRA for Control Data: As discussed herein, one or more PRAs can be implicitly/explicitly designated as control PRA. In aspects, control data can be transmitted only on these PRAs. PHR and BSR can be piggybacked in the wHL-PDU on this control PRA if PHR/BSR transmission is triggered and/or should be transmitted based on values. Also, user plane data can be included in the wHL-PDU for control

PRA if there are resources left after finishing CP data. A 1 bit flag (e.g., PDU Type) can identify wHL PDU for control PRA or that for UP PRAs.

[00127] Multiplexing of BSR, PHR, CP data and UP data in C-PDU: Since BSR, PHR, CP data and/or UP data can be multiplexed for C-PDU, a field (e.g., Field-Type) can be included in the header to handle multiplexing.

Packet Header Optimization in case of Re-segmentation of a w-HL C-PDU during ARQ Retransmission

[00128] During ARQ retransmission, if a base station provides a grant on control PRA equal to wHL C-PDU (previous TB size), there is no need for re-segmentation. However, the grant may be of a smaller size, and in that case a C-PDU (original C-PDU) in the retransmission buffer can be re-segmented. When the original C-PDU is re-segmented, an ID can be assigned to each of its re-segments to help the w-HL RX entity to recreate the original C-PDU and also to request retransmission of lost resegment(s). If some re-segment of the original C-PDU is lost, only the missed resegments can be re-sent. During retransmission of a resegment, it could potentially be segmented again to fit the retransmission grant, which can be referred to herein as second level resegmentation. In aspects, there can be multiple levels of resegmentation. For the w-HL Tx and Rx entities, potential difficulties could arise in managing IDs of multiple levels of resegmentation and to buffer multiple levels of resegmented data.

[00129] To simplify the processing (at w-HL Rx/Tx entities) and to save the buffering for ARQ retransmission, in various aspects, only the original w-HL C-PDUs can be stored/buffered in CP retransmission buffer. If a re-segmentation of an original C-PDU (in CP retransmission buffer) is performed due to say smaller grant size, the retransmission packet header can be added in such a way that each segment (of resegmentation) can be identified uniquely and can be recreated from the original w-HL C-PDU if a segment (of resegmentation) is to be retransmitted.

[00130] In our design, a w-HL C-PDU (as well as UP PDU) is of maximum size up to 75 Bytes. For resegmentation of w-HL C-PDU during ARQ retransmission, stating the start offset in Byte for a resegment is efficient as it needs only 7 bits. Therefore, a segment (of re-segmentation) can be identified via an ID to identify the original C-PDU and a start offset in bytes within the original C-PDU, as described below. To make the decoding easier at the w-HL Rx entity, a flag indicating whether this is a last segment or not can also be included.

[00131] C-Rseg-SO (7 bits): A Resegmentation Start Offset can specify a start byte of the original C-PDU (Original Header (e.g., excluding padding at the beginning, BSR and PHR subheaders) + Original Data fields) for this resegment, which can be the starting Byte number in the original C-PDU carried in this Re-segment while performing resegmentation during ARQ re-transmission of a C-PDU. For retransmission the whole C-PDU can be considered, excluding padding at beginning, BSR and PHR subheaders (e.g., original Header excluding padding at beginning, BSR and PHR subheaders + original data fields) as a data to specify the start offset of a resegment. For an example maximum C-PDU size of 600 bits (75 bytes), 7 bits (which covers up to 128 Bytes length) is enough to represent the start offset in original C-PDU.

[00132] C-RSeg-SN (10 Bits): During re-transmission each original C-PDU can be identified so that the C-PDU identification tag (PDU ID) can be used in its re-segmentation. The C-PDU identification tag (PDU ID) is discussed in various cases below. In various scenarios, C-PDU identification (PDU ID) can be based on a SDU C-SN (or UP SDU SN) (7 or 10 bits) only, or on a SDU C-SN (or UP SDU SN) with Segment number (14 or 19 bits) from the original C-PDU. A Reseg C-PDU tag id can be defined called control plane Resegment Sequence Number (C-Rseg-SN) (e.g., of 3 bits) to be transmitted in the header during ARQ retransmission of C-PDU if resegmentation is employed. The w-HL Tx entity can maintain a table with a mapping of C-Rseg-SN to the original C-PDU identification Tag (PDU ID) at least temporarily, so that the w-HL Tx entity can create the remaining resegments for future grants. Note that the w-HL Tx does not need to exchange this mapping Table information to the w-HL Rx side. After collecting all resegments for a C-Rseg-SN, the Rx side can extract the original packet, thus the mapping table information is not necessary. The original packet can have the original header (excluding padding at beginning, BSR and PHR subheaders) and original data fields. Thus, the Rx side can get the SN or SN plus Seg-N from the original header.

[00133] A 1 bit C-RSeg-SN can be employed for control PRA ARQ retransmission as there is only one TB per TTI per wUE and retransmission has higher priority. However, a C-RSeg-SN of 3 bits can be defined so that the w-HL Receive entity can avoid sending ARQ ACK per C-PDU. The w-HL Receive entity can thus have the flexibility to receive 8 C-PDUs (due to the 3 bits C-RSeg-SN) and can send a cumulative ACK to reduce ARQ ACK overhead. Alternatively, the w-HL transmit entity can send at most 8 C-PDUs without getting ARQ ACK. In place of the C-RSeg-SN, a C-PDU-SN (a SN for

each PDU) can be employed. However, by using C-RSeg-SN only for retransmission, 3 bits can be saved in the first transmission per C-PDU.

[00134] Below, packet Header design for CP data for various cases are discussed, along with a C-PDU identification tag (C-PDU ID) that can be employed for each case.

Control Plane packet Header design for w-HL data processing:

Various fields of Packet Header

[00135] In various aspects, the following fields can be included in a packet header design of a w-HL C-PDU, which can efficiently allow segmentation and concatenation of SDUs, SDU-segment and/or wHL C-PDU-Resegment. User plane data transmission related packet headers can differ from those discussed below. Table 2, below, provides a summary of several packet header fields that can be included in various aspects:

Table 2: Summary of major packet header fields and their description proposed for w-HL C-PDU.

<u>Header field</u>	<u>Header field Value</u>	<u>Header field Description</u>
<i>R (1 bit)</i>	0	Reserved for future use
<i>PDU Type (1 bit)</i>	0/1	0 = User plane Data PDU for UP PRAs; 1 = PDU for Control PRAs
<i>E (1 bit)</i>	0/1	Extension bit. 0 = No more data field after this data field. 1 = There is at least one more data field after the data field related to this subheader
<i>Field-Type (3 bits)</i>	000	BSR only; No PHR in this PDU
	001	PHR only; No BSR in this PDU
	010	BSR and PHR both; BSR (5 bits) followed by PHR (5 bits)
	011	Start of subheader for Regular User or control Plane Data (No BSR, No PHR in this PDU)
	100 - 110	Reserved for future use
	111	Padding at the beginning

Content-Type (4 bits)	0000	w-HL C-PDU from retransmission buffer of CP ARQ retransmission buffer – NOT resegmented
	0001	A segment of a resegmented w-HL C-PDU from retransmission buffer of CP ARQ retransmission buffer – PDU resegmented – NOT Last Segment
	0010	The LAST segment of a resegmented w-HL C-PDU from retransmission buffer of CP ARQ retransmission buffer –PDU resegmented –Last Segment
	0011	w-HL SDU from UL CP TX buffer – NOT Segmented
	0100	A segment of a segmented w-HL SDU from UL CP TX buffer –SDU segmented – NOT Last Segment
	0101	The LAST segment of a segmented w-HL SDU from UL CP TX buffer – SDU segmented – Last Segment
	0110	w-HL SDU from UL UP TX buffer – NOT Segmented
	0111	A segment of a segmented w-HL SDU from UL UP TX buffer –SDU segmented – NOT Last Segment
	1000	The LAST segment of a segmented w-HL SDU from UL UP TX buffer – SDU segmented – Last Segment
	1101 - 1110	Reserved for Future Use
	1111	Padding at the End
LI (7 bits)	0 to 127	Length Indicator. Specifies length in Byte of the associated data field.
SN (10 bits)	0 to 1023	Sequence number assigned to each UP w-HL SDU.
Seg-N (9 or 7 bits)	0 to 511 (9 bits) 0 to 127 (7 bits)	Segment Number of a UP SDU. A segment of a UP w-HL SDU is uniquely identified by SN and Seg-N.
C-SN (7 bits)	0 to 127	Sequence number assigned to each CP w-HL SDU.
C-Seg-N (7 bits)	0 to 127	Control Plane Segment Number of a CP SDU. A segment of a CP w-HL SDU is uniquely identified by C-SN and C-Seg-N.
Rseg-SO	0 to 127	Re-segmentation Start Offset in Byte for UP PDU. Used for resegmentation of a w-HL UP PDU during

(7 bits)		retransmission. Start Byte in the original PDU (Original Header + Original Data fields) of UP PDU contained in this segment (of resegmentation).
RSeg-SN (10 Bits)	0 to 1023	Resegmentation Sequence Number. An Id which uniquely identify an original w-HL UP PDU during retransmission. A segment (of resegmented wHL UP PDU) is uniquely identified by Rseg-SN and Rseg-SO
C-Rseg-SO (7 bits)	0 to 127	Re-segmentation Start Offset in Byte for C-PDU (CP PDU). Used for resegmentation of a w-HL CP PDU during ARQ retransmission. Start Byte in the original CP PDU (C-PDU) excluding padding at beginning, BSR and PHR subheaders (that is Original Header excluding padding at beginning, BSR and PHR subheaders + Original Data fields) contained in this segment (of resegmentation).
C-RSeg-SN (3 Bits)	0 to 7	Resegmentation Sequence Number for CP PDU. An Id which uniquely identify an original w-HL CP PDU during retransmission. A segment (of resegmented wHL CP PDU) is uniquely identified by C-Rseg-SN and C-Rseg-SO
Pad	Variable number of 0s	Padding. Used to make a PDU header/subheader Byte aligned

[00136] Length Indicator: whenever there is more than one SDUs/SDU-Segments/C-PDU-Resegments in a w-HL field, the corresponding subheader fields for all data fields except the last data field can have a length indicator field. There is one case (called Padding at the end) when the last data field can also have a length field as described below.

Procedure to adjust w-HL C-PDU in order to match its size with the allocated Grant

[00137] When PHY/L1 indicates to provide a C-PDU of a specific size, w-HL can make sure it provides L1 a w-HL C-PDU of exactly the same size as indicated by L1. The L1 transport block size (i.e., grant size for w-HL C-PDU generation indicated by L1) can be assumed to be Byte aligned. As described below, padding can be used to match the size of w-HL to the grant size.

[00138] Padding: In some situations, only a few bytes (e.g., 1, 2, 3 or 4 Bytes, etc.) of grant can be left over after including 0 or more SDUs/SDU-Segments/C-PDU-Resegments while preparing a w-HL C-PDU. The left over grant may not be sufficient to include a new subheader and a corresponding data field of at least one Byte. In another case, there is not sufficient data to fill the grant and relatively large padding (several Bytes say more than 4 Bytes) can be used to fill the grant. In such cases, padding can be added as described in the following cases and the example octets shown in FIGS. 8A, 8B, and 8C.

[00139] In the first case, referring to **FIG. 8A**, illustrated is an example of a padding subheader that can be added at the beginning of a w-HL C-PDU header when a left over grant has only one Byte to exactly match a w-HL C-PDU size to the grant size, according to various aspects described herein. In the first case, only one Byte of UL Grant is left over, and a padding sub header of 1 Byte can be added at the beginning as shown in the example of FIG. 8A. In this first case, the LI field can be omitted for the last SDU/SDU-Segment/C-PDU-Resegment subheader, as it is still the last data field. The padding header can be identified by a distinct field type (e.g., Field-Type = 111, etc.). The receiving side (w-HL Rx entity) can simply ignore the padding subheader as if this byte does not exist when it finds a padding subheader at the beginning of C-PDU header during decoding.

[00140] In the second case, referring to **FIG. 8B**, illustrated is an example of a padding subheader that can be added at the beginning of a w-HL C-PDU header when a left over grant has only two Bytes to exactly match the w-HL C-PDU size to the grant size, according to various aspects described herein. In this second case, only two Bytes of Grant are left over, and two one-Byte padding sub headers can be added to the two Bytes at the beginning, as seen in FIG. 8B. In this second case, the LI field can be omitted for the last SDU/SDU-Segment/C-PDU-Resegment subheader, as it is still the last data field. The padding header can be identified by a distinct field type (e.g., Field-Type = 111, etc.). The receiving side (w-HL Rx entity) can simply ignore padding subheaders at the beginning of the C-PDU header during decoding as if these two bytes did not exist.

[00141] In the third case, referring to **FIG. 8C**, illustrated is an example of a padding subheader that can be added at the end of a w-HL C-PDU header to enable insertion of 0 or more Bytes of padding data field at the end of a w-HL-PDU (data field) so that the w-HL C-PDU size can be matched exactly to the grant size, according to various aspects described herein. In the third case, three or more Bytes of Grant can be left

over. In the third case, sufficient grant can exist to add the LI field in the last SDU/SDU-Segment/C-PDU-Resegment subheader (of the w-HL C-PDU as constructed before padding) and add a padding subheader at the end. The padding subheader (as shown in FIG. 8C) at the end can indicate that after the last SDU/SDU-Segment/C-PDU-Resegment data field (for which there is a LI), the remaining grant can be filled with padding. The padding data field in this case can comprise 0 or more bytes. The receiving side (w-HL Rx entity) can simply ignore a remaining part (e.g., the padding part) after the last SDU/SDU-Segment/C-PDU-Resegment while decoding.

Priority Handling During Multiplexing to Create C-PDU for Transmission on Control PRA

[00142] An example set of priorities for creating a w-HL C-PDU can be as follows. The BSR and PHR can have a highest priority, which can be followed by C-PDU in the CP retransmission buffer. CP data in the CP Tx buffer can have a next highest priority. CP data can have higher priority than the UP data while creating C-PDU to be transmitted on a control PRA. UP data can be included in the C-PDU only when there is no more CP data to be transmitted. The grant left after placing BSR and PHR (when included) can be used for ARQ retransmission of C-PDU in the CP retransmission buffer. If there is grant left over, the grant can then be filled with CP data. If there is still grant left over after putting in CP data, then UP data can be placed in the C-PDU.

[00143] According to this example, the priority of various data, in decreasing order, can be as follows: (1) the BSR field can have a first (Highest) priority to be included in C-PDU; (2) the PHR field can have a second priority; (3) the C-PDU in the ARQ retransmission buffer pending to be retransmitted can have a third priority; (4) CP data can have a fourth priority; and (5) UP data can have a fifth (least) priority.

Buffer Status Report (BSR) and Power Headroom Report (PHR)

[00144] BSR can provide an estimate of UL data in a wUE's buffers to the nUE so that the nUE can assign a reasonable UL grant to the wUE. In one example, 5 bits (providing 32 possible BSR Indices) can be used to specify buffer size ranges. Table 3 below shows an example of BSR Index versus buffer size (in byte) mapping. In Table 3, buffer size represents the total data in buffers at wUE, such as in the user plane transmission buffer and the control plane transmission buffer.

Table 3: Buffer Size levels for BSR

Index (5 bits)	Buffer Size (BS) value [bytes]	Index (5 bits)	Buffer Size (BS) value [bytes]
0	BS = 0	16	4940 < BS ≤ 6074
1	0 < BS ≤ 22	17	6074 < BS ≤ 9185
2	22 < BS ≤ 45	18	9185 < BS ≤ 13888
3	45 < BS ≤ 75	19	13888 < BS ≤ 20999
4	75 < BS ≤ 97	20	20999 < BS ≤ 31752
5	97 < BS ≤ 129	21	31752 < BS ≤ 48012
6	129 < BS ≤ 150	22	48012 < BS ≤ 72598
7	150 < BS ≤ 225	23	72598 < BS ≤ 109774
8	225 < BS ≤ 375	24	109774 < BS ≤ 165989
9	375 < BS ≤ 600	25	165989 < BS ≤ 250990
10	600 < BS ≤ 922	26	250990 < BS ≤ 379519
11	922 < BS ≤ 1244	27	379519 < BS ≤ 573866
12	1244 < BS ≤ 1822	28	573866 < BS ≤ 867737
13	1822 < BS ≤ 2650	29	867737 < BS ≤ 1312097
14	2650 < BS ≤ 3822	30	1312097 < BS ≤ 3000000
15	3822 < BS ≤ 4950	31	BS > 3000000

[00145] PHR can be sent by a wUE to tell the nUE whether the wUE can transmit at a higher transmission power or not compared to the power being used by current transmission. PHR can be positive or negative. Positive PHR indicates that the wUE is not transmitting at a maximum allowed transmission power and therefore it is still capable to transmit at a higher Tx power or it is still capable of transmitting at higher throughput. If PHR is negative, the wUE is already transmitting at maximum allowed Tx power. PHR information can be used by nUE to determine whether to allocate more or less UL grant to wUE. For example, in case of a positive PHR, the nUE can allocate more PRA/resource to wUE.

[00146] In one example, 5 bits (equivalent to 32 PH indices) to specify Power headroom (PH). These 32 PH levels/indices can be mapped to measured PH values. Table 4, below, presents PH levels and an example of their mapping to measured

quantity values assuming a maximum transmission power of a wUE of 20 dBm. The range of measured quantity values represented by each power headroom index can be varied depending on allowable PRA (physical resource allocation) granularity.

Table 4: An example showing Power Headroom Levels and Power Headroom Report Mapping

PH	Power Headroom Levels/Reported Values	Measured Quantity Values
0	PH_0	$-23 \leq PH < -21$
1	PH_1	$-21 \leq PH < -19$
2	PH_2	$-19 \leq PH < -17$
3	PH_3	$-17 \leq PH < -15$
...	...	...
28	PH_28	$33 \leq PH < 35$
29	PH_29	$35 \leq PH < 37$
30	PH_30	$37 \leq PH < 39$
31	PH_31	$PH \geq 39$

Various Example cases of w-HL Header Generation

Examples of Various cases of w-HL C-PDU Headers showing Padding, BSR, PHR and a CP SDU from Uplink Control Plane Transmission buffer:

[00147] Referring to **FIG. 9A**, illustrated is an example of a C-PDU consisting of only a CP SDU from UL CP Transmission buffer. It does not have BSR or PHR, which can be indicated via a field type (e.g., Field Type = 011). The PDU-Type can be 1 here to indicate that the PDU is a C-PDU to be transmitted over control PRA. The Content-Type = 0011 can indicate that this field has a CP SDU. C-PDU ID (C-PDU Identification Tag) for Retransmission: The C-PDU in FIG. 9A can be uniquely identified by the C-SN field.

[00148] Referring to **FIG. 9B**, illustrated is an example of a C-PDU consisting of a BSR and a CP SDU from UL CP Transmission buffer. Field-Type = 000 can indicate that the PDU has a BSR field. The w-HL Receive (Rx) entity can know that the BSR is of (e.g., 5 bits) fixed size and after that the data field starts as indicated by E=1. E=1 can indicate that there is a next field. The type of data field (a CP SDU – NOT

segmented) can be identified by Content-Type field = 0011. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 9B can be uniquely identified by the C-SN field.

[00149] Referring to **FIG. 10A**, illustrated is an example of a C-PDU consisting of a PHR and a CP SDU from UL CP Transmission buffer. Field-Type = 001 can indicate that the PDU has a PHR field. The w-HL Receive entity can know that the PHR is of 5 bits fixed size and after that the data field starts as indicated by E=1. E=1 can indicate that there is a next field. The type of data field (a CP SDU – NOT segmented) can be identified by Content-Type field = 0011. C-PDU ID (C-PDU Identification Tag) for Retransmission: C-PDU in FIG. 10A can be uniquely identified by C-SN field.

[00150] Referring to **FIG. 10B**, illustrated is an example of a C-PDU consisting of a BSR, a PHR and a CP SDU from UL CP Transmission buffer. Field-Type = 010 can indicate that the PDU has a BSR followed by a PHR field. The w-HL Receive entity can know that 5 bits BSR-field is followed by a 5 bits-PHR field. After the BSR and PHR fields, the data field can start as indicated by E=1. E=1 can indicate that there is a next field. The type of data field (a CP SDU – NOT segmented) can be identified by Content-Type field 0011. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 10B can be uniquely identified by C-SN field.

[00151] Referring to **FIG. 11**, illustrated is an example of a C-PDU similar to that in FIG. 10B. However, a 1 Byte padding subheader can be added at the beginning of the PDU to fill the grant. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 11 can be uniquely identified by C-SN field.

[00152] Referring to **FIG. 12**, illustrated is an example of a C-PDU similar to that in FIG. 10B. However, two 1-Byte padding subheaders are added at the beginning of the PDU to fill the grant. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 12 can be uniquely identified by C-SN field.

[00153] Referring to **FIG. 13**, illustrated is an example of a C-PDU similar to that in Fig. 10B. However, it has a padding subheader at the end to fill the remaining grant. A length indicator field can be added to specify the length of the CP-SDU field so that the w-HL receive entity can ignore all remaining bytes after getting CP-SDU. C-PDU ID (C-PDU Identification Tag): the C-PDU in FIG. 13 can be uniquely identified by C-SN field.

Examples of w-HL C-PDU Headers showing BSR, PHR and a CP SDU Segment from UL CP Transmission:

[00154] When a CP SDU is segmented, each segment can have a segment number (C-Seg-N) along with the SDU's SN. Referring to **FIG. 14**, illustrated is an example a w-HL C-PDU having a BSR, a PHR, and a CP-SDU segment (that is not the last segment of this SDU) from a UL CP Tx buffer. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 14 can be uniquely identified by C-SN and C-Seg-N field.

[00155] Referring to **FIG. 15**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR and a CP-SDU segment (that is the last segment of this SDU) from the UL CP TX buffer. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 15 can be uniquely identified by C-SN and C-Seg-N field.

Examples of w-HL C-PDU Headers showing BSR, PHR, UP SDU and/or UP SDU Segment from UL UP Transmission:

[00156] As discussed above, CP data can have a higher priority than the UP data while creating a C-PDU to be transmitted. In such aspects, UP data can be included in the C-PDU only when there is no more CP data to be transmitted. Thus, the grant left after placing BSR and PHR can be used for ARQ retransmission of C-PDU in retransmission buffer. If there is grant left over, the grant can then be filled with CP data. If there is still grant left over after putting CP data, then UP data can be placed in the C-PDU.

[00157] The following examples represent cases when there is no data in the CP transmission buffer or in the CP ARQ retransmission buffer.

[00158] Referring to **FIG. 16A**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU from UL User plane Tx buffer. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 16A can be uniquely identified by SN field.

[00159] Referring to **FIG. 16B**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU segment (not last segment of this SDU) from UL user plane TX buffer. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 16B can be uniquely identified by SN and Seg-N fields.

[00160] Referring to **FIG. 17A**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR and a UP-SDU segment (last segment of this SDU) from UL user plane TX

buffer. C-PDU ID (C-PDU Identification Tag) for Retransmission: the C-PDU in FIG. 17A can be uniquely identified by SN and Seg-N fields.

Examples of w-HL C-PDU Headers showing BSR, PHR, C-PDU or C-PDU Segment from UL CP Retransmission buffer:

[00161] As discussed above, if there are control plane data in retransmission buffer waiting for retransmission, these data can have higher priority than the CP data and UP data in Transmission buffers. A w-HL C-PDU can be resegmented during retransmission as the grant can be smaller than the w-HL C-PDU. In aspects, when it is possible to include the entire w-HL C-PDU in the grant, the w-HL C-PDU is not segmented during retransmission.

[00162] Referring to **FIG. 17B**, illustrated is an example of an ARQ retransmission of a w-HL C-PDU having a BSR, a PHR and a C-PDU (not resegmented) from UL ARQ control plane retransmission buffer.

[00163] Referring to **FIG. 18A**, illustrated is an example of an ARQ retransmission of a w-HL C-PDU having a BSR, a PHR and a C-PDU segment (not last segment of this resegmented C-PDU) from UL ARQ control plane retransmission buffer. Re-segmentation of a w-HL C-PDU in retransmission buffer can be performed due to a smaller grant.

[00164] Referring to **FIG. 18B**, illustrated is an example of an ARQ retransmission of a w-HL C-PDU segment having a BSR, a PHR and a C-PDU Segment (last segment of this resegmented C-PDU) from UL ARQ control plane retransmission buffer. Re-segmentation of a w-HL C-PDU in retransmission buffer can be performed due to a smaller grant. Here this segment is the last segment, however, the grant is not sufficient to accommodate any other data field.

Examples of w-HL C-PDU Headers showing BSR, PHR, UP SDU, CP SDU, CP SDU segment and/or UP SDU Segment:

[00165] Referring to **FIG. 19**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a CP-SDU from UL control plane TX buffer and an UP-SDU from UL user plane TX buffer.

[00166] Referring to **FIG. 20**, illustrated is an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU from UL control plane TX buffer and an UP-SDU segment (not last segment of the UP-SDU) from UL user plane TX buffer.

[00167] Referring to **FIG. 21**, illustrated is an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU segment (last segment of this SDU) from UL control plane TX buffer and an UP-SDU from UL user plane TX buffer.

[00168] Referring to **FIG. 22**, illustrated is an example of a w-HL CP PDU having a BSR, a PHR, a CP-SDU segment (last segment of this SDU) from UL control plane TX buffer, and a UP-SDU Segment (not last segment of this SDU) from UL user plane TX buffer.

Examples of w-HL C-PDU Headers showing BSR, PHR, C-PDU, C-PDU Segment, CP/UP SDU and/or CP/UP SDU Segment:

[00169] Referring to **FIG. 23**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer and a UP-SDU from UL user plane TX buffer. In this example, there is only one C-PDU in control plane retransmission buffer and there is no data in control plane transmission buffer.

[00170] Referring to **FIG. 24**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer and a UP-SDU segment (not last segment) from UL user plane TX buffer. In this example, there is only one C-PDU in control plane retransmission buffer and there is no data in control plane transmission buffer.

[00171] Referring to **FIG. 25**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU (NOT resegmented) from UL control plane retransmission buffer, a CP SDU from UL control plane transmission buffer and a UP-SDU (not segmented) from UL user plane TX buffer. In this example, there is only one C-PDU in control plane retransmission buffer and only one CP SDU in control plane transmission buffer.

[00172] Referring to **FIG. 26**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU Segment (Last Segment of this resegmented C-PDU) from UL control plane retransmission buffer and a CP-SDU from UL Control plane TX buffer. In this example, there is only one C-PDU in control plane retransmission buffer.

[00173] Referring to **FIG. 27**, illustrated is an example of a w-HL C-PDU having a BSR, a PHR, a C-PDU Segment (Last Segment of this resegmented C-PDU) from UL control plane retransmission buffer and a CP-SDU Segment (Not last Segment) from UL Control plane TX buffer. In this example, there is only one C-PDU in control plane Retransmission buffer.

[00174] Examples herein can include subject matter such as a method, means for performing acts or blocks of the method, at least one machine-readable medium including executable instructions that, when performed by a machine (e.g., a processor with memory, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like) cause the machine to perform acts of the method or of an apparatus or system for concurrent communication using multiple communication technologies according to embodiments and examples described.

[00175] Example 1 is an apparatus configured to be employed within a User Equipment (UE), comprising a memory; and one or more processors configured to: assign a distinct sequence number to each of one or more control plane (CP) packets from a wearable radio resource control (w-RRC) layer; buffer the one or more CP packets to a CP transmission buffer; determine a physical resource assignment (PRA) and an allocated size for a wearable higher layer (w-HL) control protocol data unit (C-PDU); generate the w-HL C-PDU based at least in part on the one or more CP packets buffered to the CP transmission buffer, the PRA, and the allocated size; add a packet header to the w-HL C-PDU; and provide the w-HL C-PDU to a physical layer based on the PRA.

[00176] Example 2 comprises the subject matter of any variation of any of example(s) 1, wherein the one or more processors are further configured to generate the w-HL C-PDU based at least in part on one or more of a buffer status report (BSR), a power headroom report (PHR), a CP retransmission buffer, a user plane (UP) transmission buffer, or a UP retransmission buffer.

[00177] Example 3 comprises the subject matter of any variation of any of example(s) 2, wherein the one or more processors are further configured to determine distinct priorities for each of the CP transmission buffer, the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, and the UP retransmission buffer.

[00178] Example 4 comprises the subject matter of any variation of any of example(s) 3, wherein the one or more processors are further configured to: generate the w-HL C-PDU based at least in part on multiplexing the CP transmission buffer and the one or more of the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, or the UP retransmission buffer, wherein the multiplexing is based at least in part on the distinct priorities determined for each of the CP transmission buffer, the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, and the UP retransmission buffer.

[00179] Example 5 comprises the subject matter of any variation of any of example(s) 2-4, wherein the one or more processors are further configured to: generate one or more segments via segmenting one or more CP packets buffered to the CP transmission buffer, segmenting one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or resegmenting one or more previously generated segments, wherein the w-HL C-PDU is generated based at least in part on the one or more segments.

[00180] Example 6 comprises the subject matter of any variation of any of example(s) 2-4, wherein the one or more processors are further configured to generate the w-HL C-PDU based at least in part on combining two or more of: one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.

[00181] Example 7 comprises the subject matter of any variation of any of example(s) 2-4, wherein the one or more processors are configured to make a determination whether to indicate at least one of the BSR or the PHR via the w-HL C-PDU, and wherein the w-HL C-PDU comprises the at least one of the BSR or the PHR when the determination is positive.

[00182] Example 8 comprises the subject matter of any variation of any of example(s) 1-4, wherein the packet header comprises two or more subheaders.

[00183] Example 9 comprises the subject matter of any variation of any of example(s) 1-4, wherein the one or more processors are further configured to adjust a size of the w-HL C-PDU via padding to match the allocated size.

[00184] Example 10 comprises the subject matter of any variation of any of example(s) 1-4, wherein the one or more processors are further configured to process at least one hybrid automatic repeat request (HARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are configured to employ a retransmission mechanism at a physical layer transport block (TB) level in response to the at least one HARQ ACK/NACK response comprising a HARQ NACK.

[00185] Example 11 comprises the subject matter of any variation of any of example(s) 1-4, wherein the one or more processors are further configured to process at least one automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are further configured to employ a retransmission mechanism at a w-

HL C-PDU level in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK.

[00186] Example 12 comprises the subject matter of any variation of any of example(s) 11, wherein, in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK, the one or more processors are further configured to: determine a new PRA and a new allocated size for the w-HL C-PDU; and based on the new allocated size, at least one of re-segment the w-HL C-PDU, or combine the w-HL C-PDU with at least one of one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.

[00187] Example 13 comprises the subject matter of any variation of any of example(s) 1-4, wherein the UE is a wearable UE (w-UE), and wherein the one or more processors are configured to determine the PRA and the allocated size based on an uplink (UL) grant.

[00188] Example 14 comprises the subject matter of any variation of any of example(s) 1-4, wherein the UE is a network UE (n-UE).

[00189] Example 15 comprises the subject matter of any variation of any of example(s) 2-4, wherein the one or more processors are further configured to: generate one or more segments via segmenting one or more CP packets buffered to the CP transmission buffer, segmenting one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or resegmenting one or more previously generated segments, wherein the w-HL C-PDU is generated based at least in part on the one or more segments.

[00190] Example 16 comprises the subject matter of any variation of any of example(s) 2-4 or 15, wherein the one or more processors are further configured to generate the w-HL C-PDU based at least in part on combining two or more of: one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.

[00191] Example 17 comprises the subject matter of any variation of any of example(s) 2-4 or 15-16, wherein the one or more processors are configured to make a determination whether to indicate at least one of the BSR or the PHR via the w-HL C-PDU, and wherein the w-HL C-PDU comprises the at least one of the BSR or the PHR when the determination is positive.

[00192] Example 18 comprises the subject matter of any variation of any of example(s) 1-4 or 15-16, wherein the packet header comprises two or more subheaders.

[00193] Example 19 comprises the subject matter of any variation of any of example(s) 1-4 or 15-18, wherein the one or more processors are further configured to adjust a size of the w-HL C-PDU via padding to match the allocated size.

[00194] Example 20 comprises the subject matter of any variation of any of example(s) 1-4 or 15-19, wherein the one or more processors are further configured to process at least one hybrid automatic repeat request (HARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are configured to employ a retransmission mechanism at a physical layer transport block (TB) level in response to the at least one HARQ ACK/NACK response comprising a HARQ NACK.

[00195] Example 21 comprises the subject matter of any variation of any of example(s) 1-4 or 15-20, wherein the one or more processors are further configured to process at least one automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are further configured to employ a retransmission mechanism at a w-HL C-PDU level in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK.

[00196] Example 22 comprises the subject matter of any variation of any of example(s) 21, wherein, in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK, the one or more processors are further configured to: determine a new PRA and a new allocated size for the w-HL C-PDU; and based on the new allocated size, at least one of re-segment the w-HL C-PDU, or combine the w-HL C-PDU with at least one of one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.

[00197] Example 23 is an apparatus configured to be employed within a User Equipment (UE), comprising a memory; and one or more processors configured to: generate one or more wearable higher layer (w-HL) control protocol data units (C-PDUs) from one or more physical layer transport blocks (TBs); provide the one or more w-HL C-PDUs to the w-HL; generate a plurality of w-HL control service data units (C-SDUs) from the one or more w-HL C-PDUs; determine an ordering of the plurality of w-HL SDUs based on a distinct sequence number (SN) associated with each w-HL SDU

of the plurality of w-HL SDUs; and deliver the plurality of w-HL C-SDUs to a wearable radio resource control (w-RRC) layer based on the ordering.

[00198] Example 24 comprises the subject matter of any variation of any of example(s) 23, wherein the one or more processors are further configured to generate one or more hybrid automatic repeat request (HARQ) ACK/NACK (acknowledgement/negative acknowledgement) responses in connection with the one or more physical layer TBs.

[00199] Example 25 comprises the subject matter of any variation of any of example(s) 23, wherein the one or more processors are further configured to generate one or more automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) responses in connection with the one or more w-HL C-PDUs.

[00200] Example 26 comprises the subject matter of any variation of any of example(s) 23, wherein a first w-HL C-PDU of the one or more w-HL C-PDUs comprises a multiplexing of two or more of a segment of a first w-HL C-SDU of the plurality of w-HL C-SDUs, a second w-HL C-SDU of the plurality of w-HL C-SDUs, a buffer status report (BSR), a power headroom report (PHR), a segment of a first user plane (UP) packet, or a second UP packet.

[00201] Example 27 comprises the subject matter of any variation of any of example(s) 23, wherein a first w-HL C-PDU of the one or more w-HL C-PDUs comprises a header comprising a plurality of subheaders.

[00202] Example 28 comprises the subject matter of any variation of any of example(s) 23-27, wherein the UE is a wearable UE (w-UE).

[00203] Example 29 comprises the subject matter of any variation of any of example(s) 23-27, wherein the UE is a network UE (n-UE), and wherein the one or more processors are configured to generate one or more uplink (UL) grants that indicate one or more physical resource assignments (PRAs), wherein the one or more physical layer TBs correspond to the one or more PRAs.

[00204] Example 30 comprises the subject matter of any variation of any of example(s) 29, wherein the one or more UL grants indicates grant sizes that correspond to sizes of the one or more w-HL C-PDUs.

[00205] Example 31 comprises the subject matter of any variation of any of example(s) 23-24, wherein the one or more processors are further configured to generate one or more automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) responses in connection with the one or more w-HL C-PDUs.

[00206] Example 32 is a machine readable medium comprising instructions that, when executed, cause a wearable User Equipment (w-UE) to: receive one or more wearable higher layer (w-HL) control service data units (C-SDUs) from a wearable radio resource control (w-RRC) layer; assign a unique sequence number (SN) to each of the one or more w-HL C-SDUs; store the one or more w-HL C-SDUs in an uplink (UL) control plane (CP) transmission buffer; receive a UL grant that indicates a physical resource assignment (PRA) and a grant size; generate a w-HL control protocol data unit (C-PDU) based at least in part on the UL grant, wherein the w-HL C-PDU comprises one or more of a buffer status report (BSR), a power headroom report (PHR), the UL CP transmission buffer, a UL CP retransmission buffer, a UL user plane (UP) transmission buffer, or a UL UP retransmission buffer; and pass the w-HL C-PDU to a physical layer.

[00207] Example 33 comprises the subject matter of any variation of any of example(s) 32, wherein the w-HL C-PDU comprises a multiplexing based on two or more of the BSR, the PHR, the UL CP transmission buffer, the UL CP retransmission buffer, the UL UP transmission buffer, or the UL UP retransmission buffer.

[00208] Example 34 comprises the subject matter of any variation of any of example(s) 32-33, wherein the instructions, when executed, further cause the UE to employ an automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) retransmission mechanism at a w-HL C-PDU level and a hybrid ARQ (HARQ) ACK/NACK retransmission mechanism at a physical layer transport block (TB) level.

[00209] Example 35 comprises the subject matter of any variation of any of example(s) 32-33, wherein the w-HL C-PDU header comprises multiple subheaders.

[00210] Example 36 is an apparatus configured to be employed within a User Equipment (UE), comprising means for storing configured to store instructions; and means for processing configured to execute the instructions to: receive one or more wearable higher layer (w-HL) control service data units (C-SDUs) from a wearable radio resource control (w-RRC) layer; assign a unique sequence number (SN) to each of the one or more w-HL C-SDUs; store the one or more w-HL C-SDUs in an uplink (UL) control plane (CP) transmission buffer; receive a UL grant that indicates a physical resource assignment (PRA) and a grant size; generate a w-HL control protocol data unit (C-PDU) based at least in part on the UL grant, wherein the w-HL C-PDU comprises one or more of a buffer status report (BSR), a power headroom report (PHR), the UL CP transmission buffer, a UL CP retransmission buffer, a UL user plane (UP) transmission buffer, or a UL UP retransmission buffer; and pass the w-HL C-PDU to a physical layer.

[00211] Example 37 comprises the subject matter of any variation of any of example(s) 36, wherein the w-HL C-PDU comprises a multiplexing based on two or more of the BSR, the PHR, the UL CP transmission buffer, the UL CP retransmission buffer, the UL UP transmission buffer, or the UL UP retransmission buffer.

[00212] Example 38 comprises the subject matter of any variation of any of example(s) 36-37, wherein the means for processing are further configured to execute the instructions to employ an automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) retransmission mechanism at a w-HL C-PDU level and a hybrid ARQ (HARQ) ACK/NACK retransmission mechanism at a physical layer transport block (TB) level.

[00213] Example 39 comprises the subject matter of any variation of any of example(s) 36-37, wherein the w-HL C-PDU header comprises multiple subheaders.

[00214] The above description of illustrated embodiments of the subject disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the disclosed embodiments to the precise forms disclosed. While specific embodiments and examples are described herein for illustrative purposes, various modifications are possible that are considered within the scope of such embodiments and examples, as those skilled in the relevant art can recognize.

[00215] In this regard, while the disclosed subject matter has been described in connection with various embodiments and corresponding Figures, where applicable, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments for performing the same, similar, alternative, or substitute function of the disclosed subject matter without deviating therefrom. Therefore, the disclosed subject matter should not be limited to any single embodiment described herein, but rather should be construed in breadth and scope in accordance with the appended claims below.

[00216] In particular regard to the various functions performed by the above described components or structures (assemblies, devices, circuits, systems, etc.), the terms (including a reference to a “means”) used to describe such components are intended to correspond, unless otherwise indicated, to any component or structure which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations. In addition, while a particular feature may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the

other implementations as may be desired and advantageous for any given or particular application.

CLAIMS

What is claimed is:

1. An apparatus configured to be employed within a User Equipment (UE), comprising:
 - a memory; and
 - one or more processors configured to:
 - assign a distinct sequence number to each of one or more control plane (CP) packets from a wearable radio resource control (w-RRC) layer;
 - buffer the one or more CP packets to a CP transmission buffer;
 - determine a physical resource assignment (PRA) and an allocated size for a wearable higher layer (w-HL) control protocol data unit (C-PDU);
 - generate the w-HL C-PDU based at least in part on the one or more CP packets buffered to the CP transmission buffer, the PRA, and the allocated size;
 - add a packet header to the w-HL C-PDU; and
 - provide the w-HL C-PDU to a physical layer based on the PRA.
2. The apparatus of claim 1, wherein the one or more processors are further configured to generate the w-HL C-PDU based at least in part on one or more of a buffer status report (BSR), a power headroom report (PHR), a CP retransmission buffer, a user plane (UP) transmission buffer, or a UP retransmission buffer.
3. The apparatus of claim 2, wherein the one or more processors are further configured to determine distinct priorities for each of the CP transmission buffer, the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, and the UP retransmission buffer.
4. The apparatus of claim 3, wherein the one or more processors are further configured to:
 - generate the w-HL C-PDU based at least in part on multiplexing the CP transmission buffer and the one or more of the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, or the UP retransmission buffer,
 - wherein the multiplexing is based at least in part on the distinct priorities determined for each of the CP transmission buffer, the CP retransmission buffer, the BSR, the PHR, the UP transmission buffer, and the UP retransmission buffer.

5. The apparatus of any of claims 2-4, wherein the one or more processors are further configured to:

generate one or more segments via segmenting one or more CP packets buffered to the CP transmission buffer, segmenting one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or resegmenting one or more previously generated segments,

wherein the w-HL C-PDU is generated based at least in part on the one or more segments.

6. The apparatus of any of claims 2-4, wherein the one or more processors are further configured to generate the w-HL C-PDU based at least in part on combining two or more of: one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.

7. The apparatus of any of claims 2-4, wherein the one or more processors are configured to make a determination whether to indicate at least one of the BSR or the PHR via the w-HL C-PDU, and wherein the w-HL C-PDU comprises the at least one of the BSR or the PHR when the determination is positive.

8. The apparatus of any of claims 1-4, wherein the packet header comprises two or more subheaders.

9. The apparatus of any of claims 1-4, wherein the one or more processors are further configured to adjust a size of the w-HL C-PDU via padding to match the allocated size.

10. The apparatus of any of claims 1-4, wherein the one or more processors are further configured to process at least one hybrid automatic repeat request (HARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are configured to employ a retransmission mechanism at a physical layer transport block (TB) level in response to the at least one HARQ ACK/NACK response comprising a HARQ NACK.

11. The apparatus of any of claims 1-4, wherein the one or more processors are further configured to process at least one automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) response in connection with the w-HL C-PDU, wherein the one or more processors are further configured to employ a retransmission mechanism at a w-HL C-PDU level in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK.
12. The apparatus of claim 11, wherein, in response to the at least one ARQ ACK/NACK response comprising an ARQ NACK, the one or more processors are further configured to:
- determine a new PRA and a new allocated size for the w-HL C-PDU; and
 - based on the new allocated size, at least one of re-segment the w-HL C-PDU, or combine the w-HL C-PDU with at least one of one or more CP packets buffered to the CP transmission buffer, one or more prior w-HL C-PDUs buffered to the CP retransmission buffer, or one or more segments.
13. The apparatus of any of claims 1-4, wherein the UE is a wearable UE (w-UE), and wherein the one or more processors are configured to determine the PRA and the allocated size based on an uplink (UL) grant.
14. The apparatus of any of claims 1-4, wherein the UE is a network UE (n-UE).
15. An apparatus configured to be employed within a User Equipment (UE), comprising:
- a memory; and
 - one or more processors configured to:
 - generate one or more wearable higher layer (w-HL) control protocol data units (C-PDUs) from one or more physical layer transport blocks (TBs);
 - provide the one or more w-HL C-PDUs to the w-HL;
 - generate a plurality of w-HL control service data units (C-SDUs) from the one or more w-HL C-PDUs;
 - determine an ordering of the plurality of w-HL SDUs based on a distinct sequence number (SN) associated with each w-HL SDU of the plurality of w-HL SDUs; and

deliver the plurality of w-HL C-SDUs to a wearable radio resource control (w-RRC) layer based on the ordering.

16. The apparatus of claim 15, wherein the one or more processors are further configured to generate one or more hybrid automatic repeat request (HARQ) ACK/NACK (acknowledgement/negative acknowledgement) responses in connection with the one or more physical layer TBs.

17. The apparatus of claim 15, wherein the one or more processors are further configured to generate one or more automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) responses in connection with the one or more w-HL C-PDUs.

18. The apparatus of claim 15, wherein a first w-HL C-PDU of the one or more w-HL C-PDUs comprises a multiplexing of two or more of a segment of a first w-HL C-SDU of the plurality of w-HL C-SDUs, a second w-HL C-SDU of the plurality of w-HL C-SDUs, a buffer status report (BSR), a power headroom report (PHR), a segment of a first user plane (UP) packet, or a second UP packet.

19. The apparatus of claim 15, wherein a first w-HL C-PDU of the one or more w-HL C-PDUs comprises a header comprising a plurality of subheaders.

20. The apparatus of any of claims 15-19, wherein the UE is a wearable UE (w-UE).

21. The apparatus of any of claims 15-19, wherein the UE is a network UE (n-UE), and wherein the one or more processors are configured to generate one or more uplink (UL) grants that indicate one or more physical resource assignments (PRAs), wherein the one or more physical layer TBs correspond to the one or more PRAs.

22. The apparatus of claim 21, wherein the one or more UL grants indicates grant sizes that correspond to sizes of the one or more w-HL C-PDUs.

23. A machine readable medium comprising instructions that, when executed, cause a wearable User Equipment (w-UE) to:

receive one or more wearable higher layer (w-HL) control service data units (C-SDUs) from a wearable radio resource control (w-RRC) layer;

assign a unique sequence number (SN) to each of the one or more w-HL C-SDUs;

store the one or more w-HL C-SDUs in a uplink (UL) control plane (CP) transmission buffer;

receive a UL grant that indicates a physical resource assignment (PRA) and a grant size;

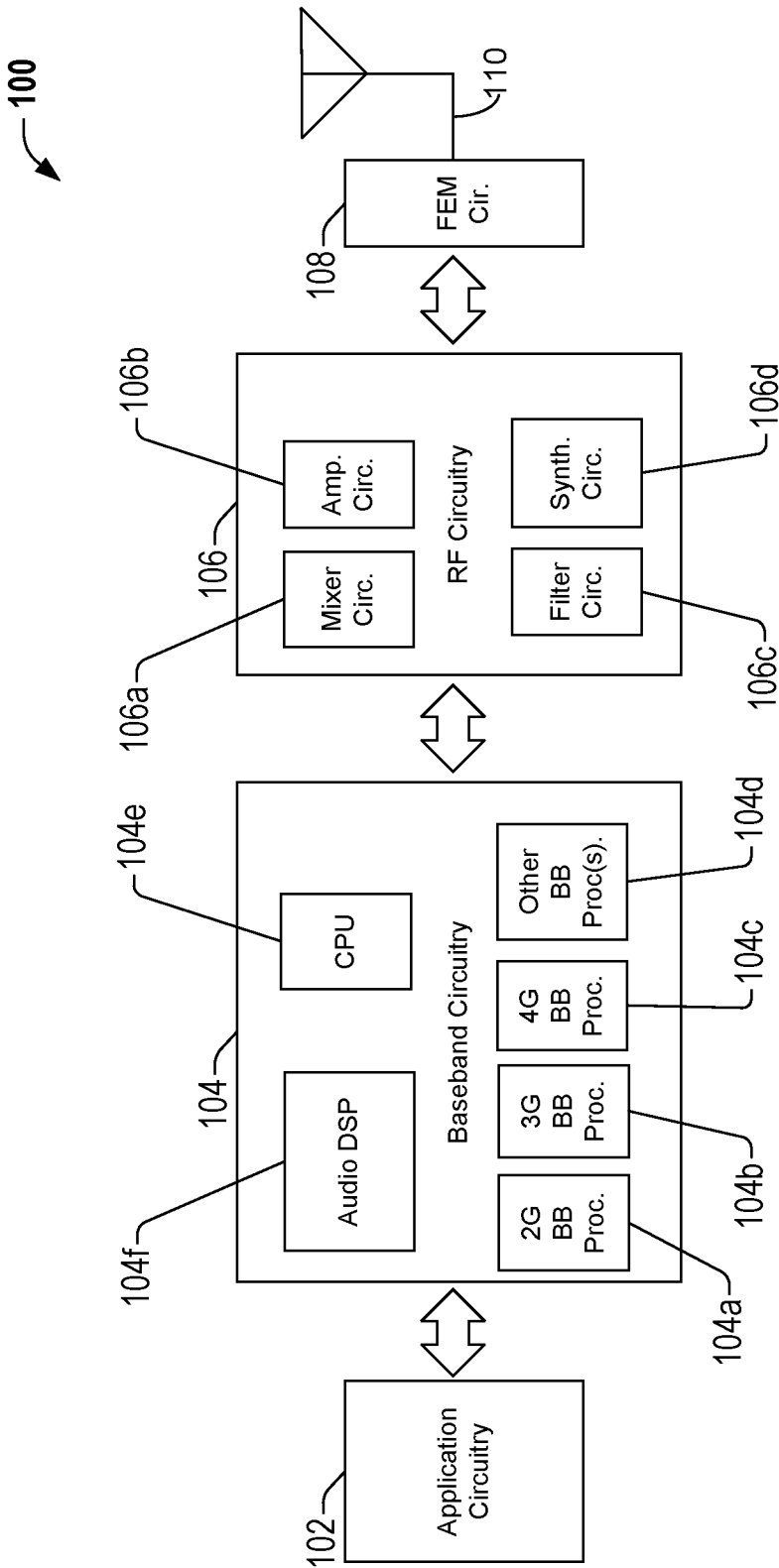
generate a w-HL control protocol data unit (C-PDU) based at least in part on the UL grant, wherein the w-HL C-PDU comprises one or more of a buffer status report (BSR), a power headroom report (PHR), the UL CP transmission buffer, a UL CP retransmission buffer, a UL user plane (UP) transmission buffer, or a UL UP retransmission buffer; and

pass the w-HL C-PDU to a physical layer.

24. The machine readable medium of claim 23, wherein the w-HL C-PDU comprises a multiplexing based on two or more of the BSR, the PHR, the UL CP transmission buffer, the UL CP retransmission buffer, the UL UP transmission buffer, or the UL UP retransmission buffer.

25. The machine readable medium of any of claims 23-24, wherein the instructions, when executed, further cause the UE to employ an automatic repeat request (ARQ) ACK/NACK (acknowledgement/negative acknowledgement) retransmission mechanism at a w-HL C-PDU level and a hybrid ARQ (HARQ) ACK/NACK retransmission mechanism at a physical layer transport block (TB) level.

26. The machine readable medium of any of claims 23-24, wherein the w-HL C-PDU header comprises multiple subheaders.



Example UE

FIG. 1

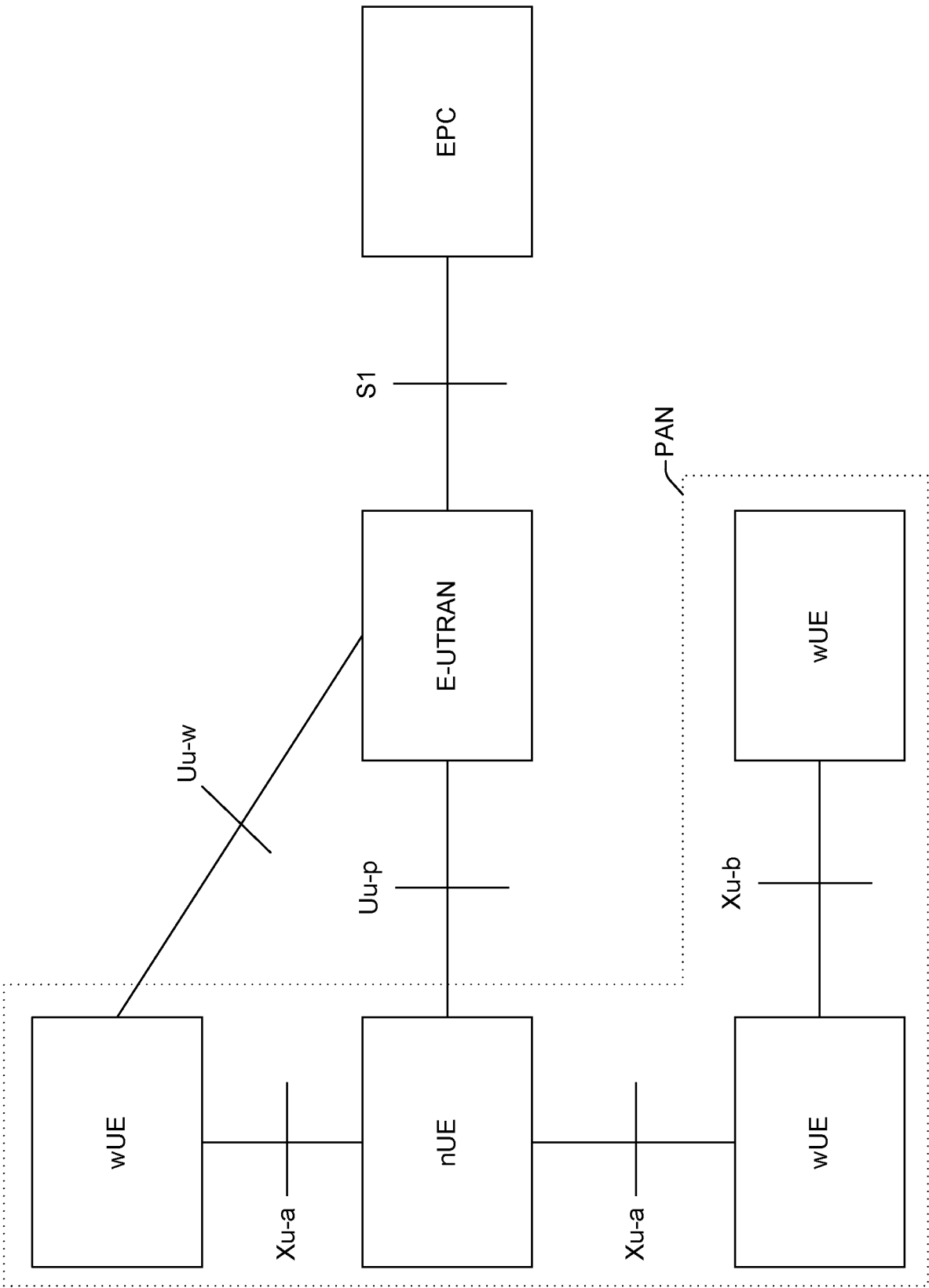


FIG. 2

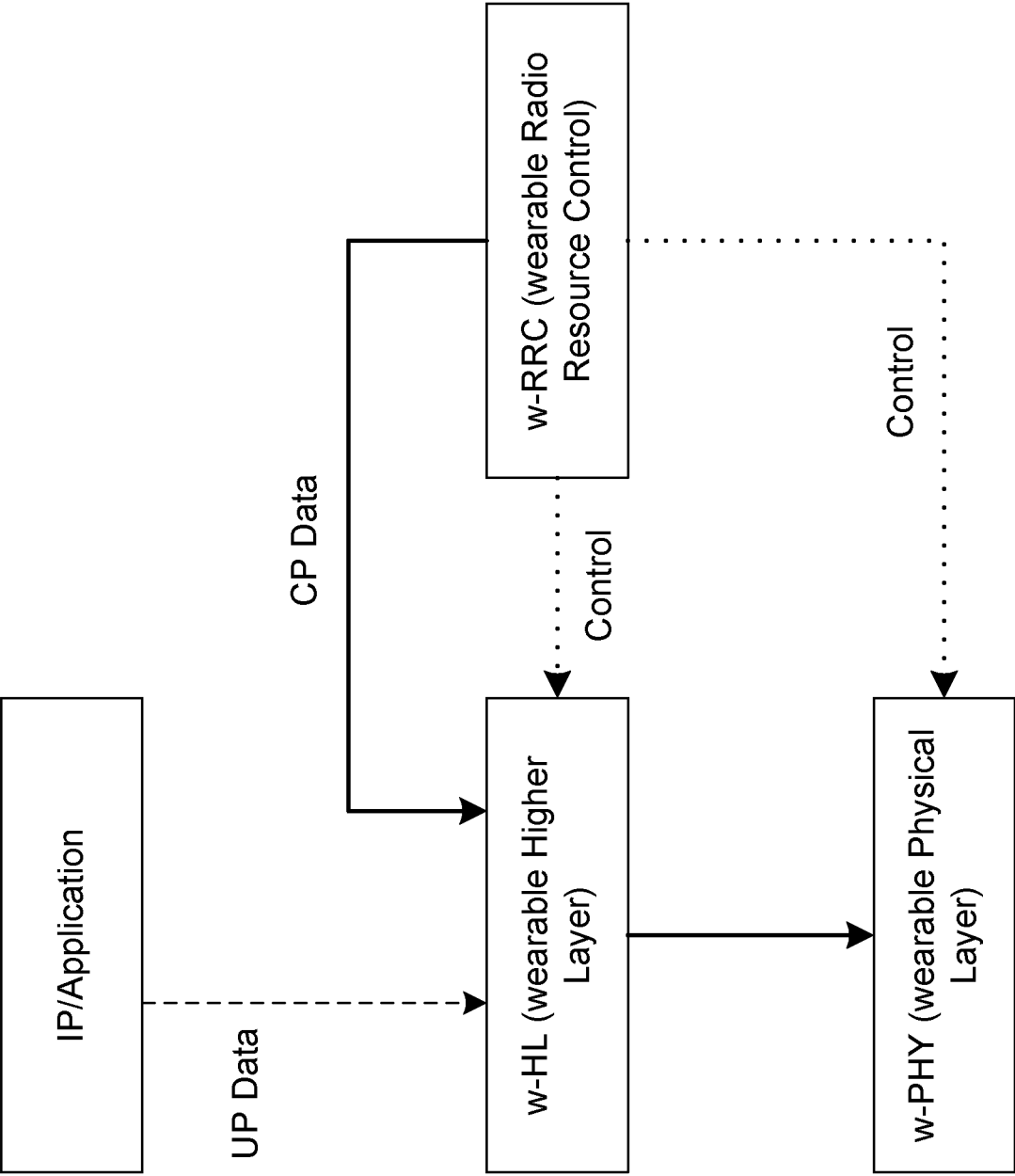


FIG. 3

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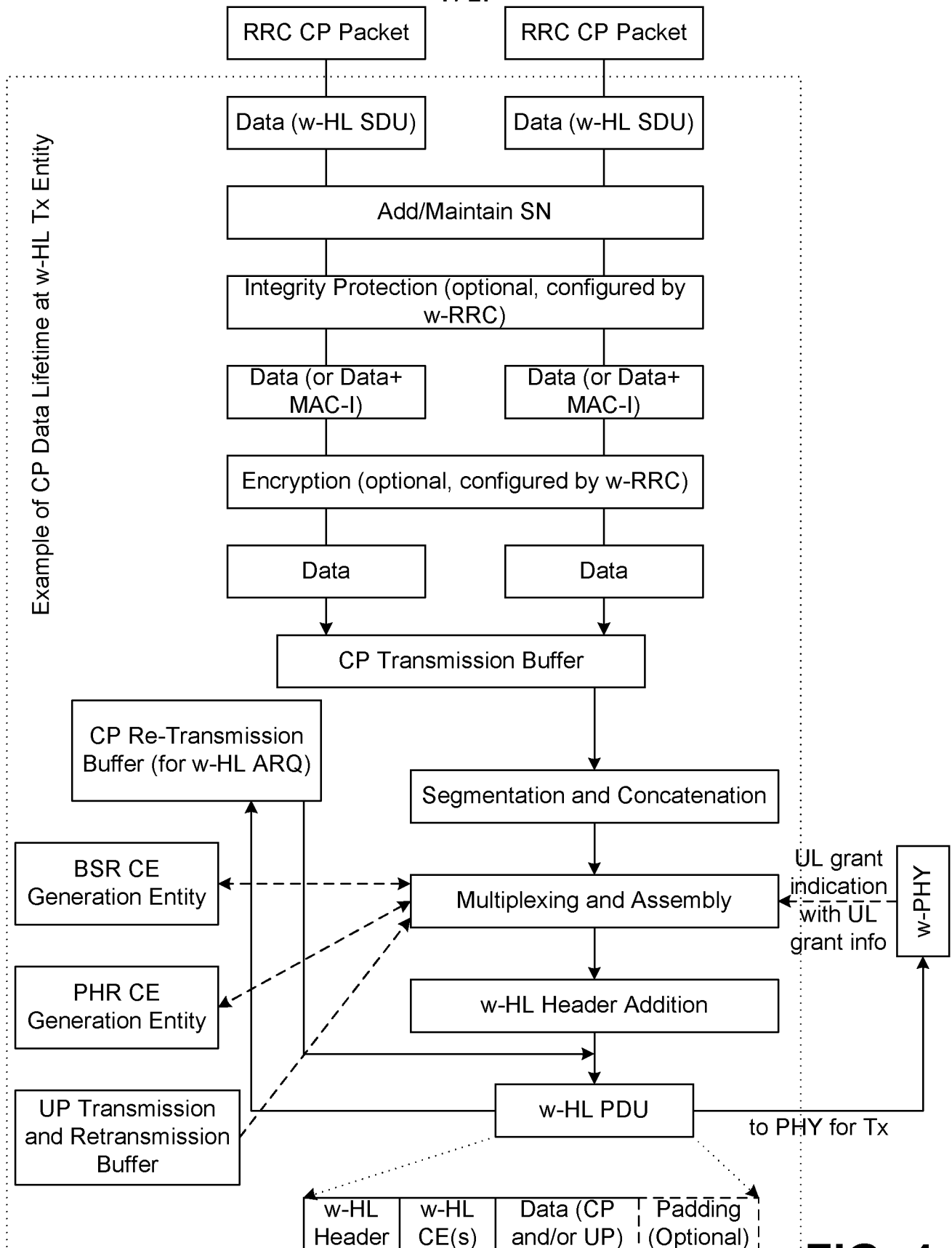


FIG. 4

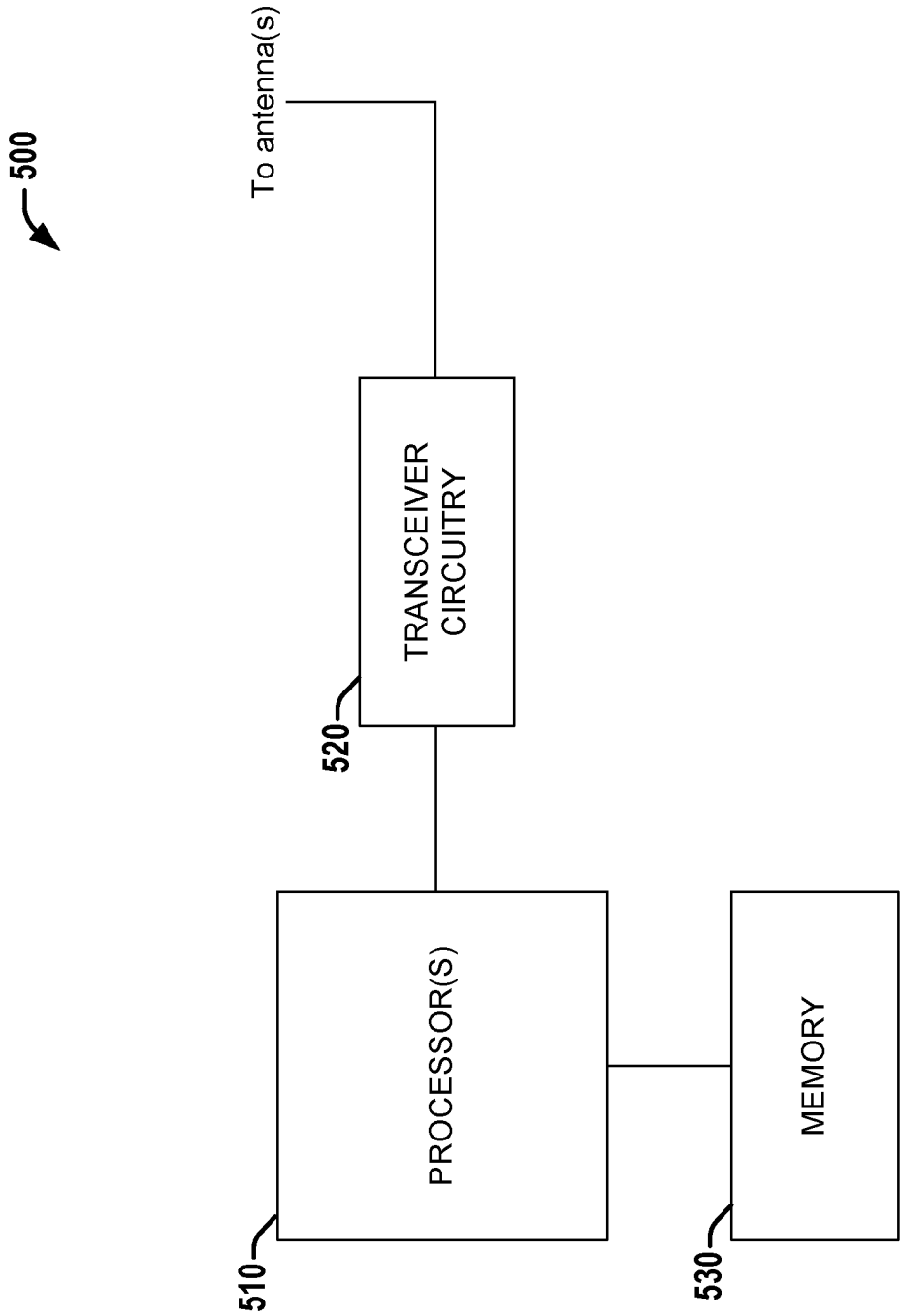


FIG. 5

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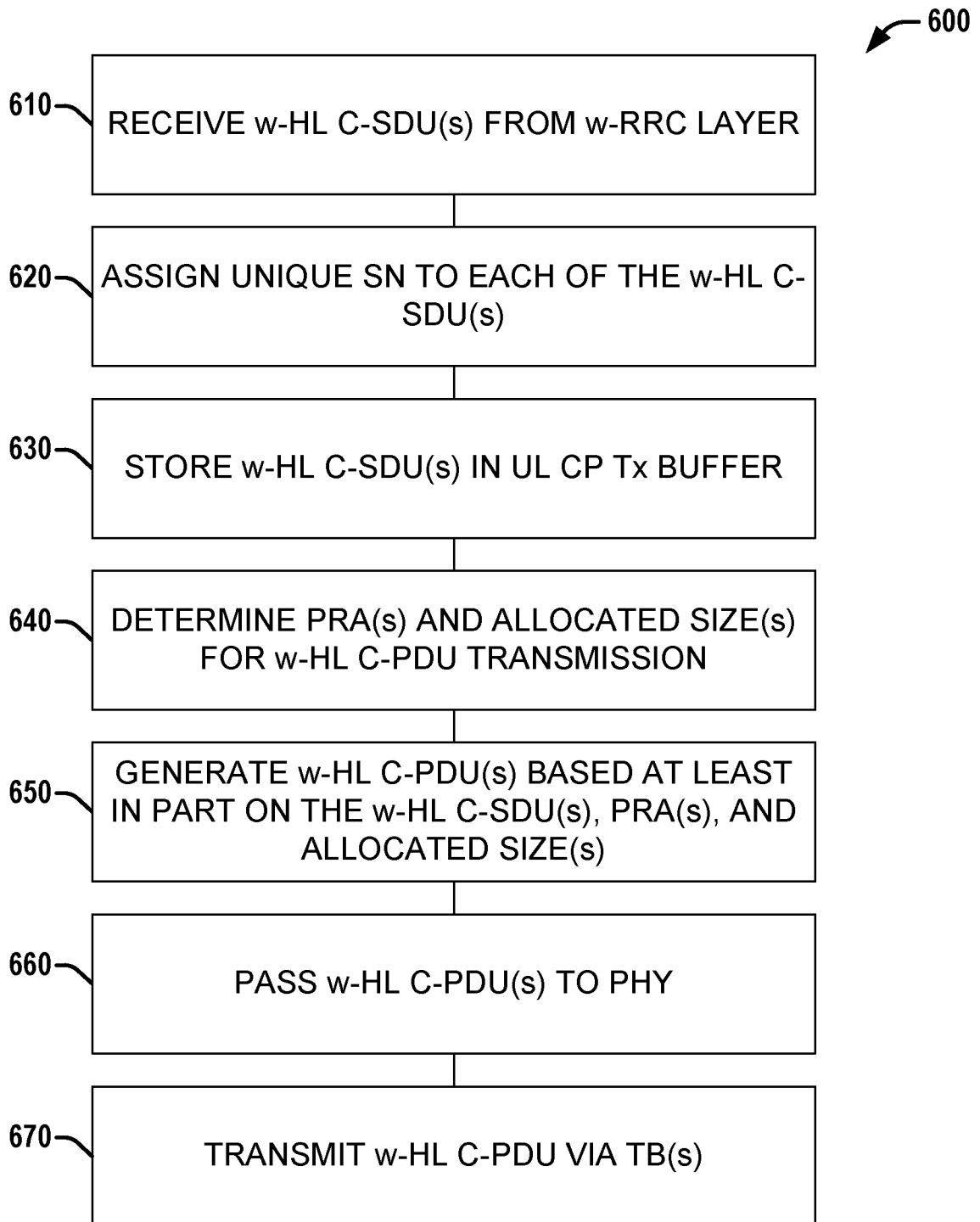


FIG. 6

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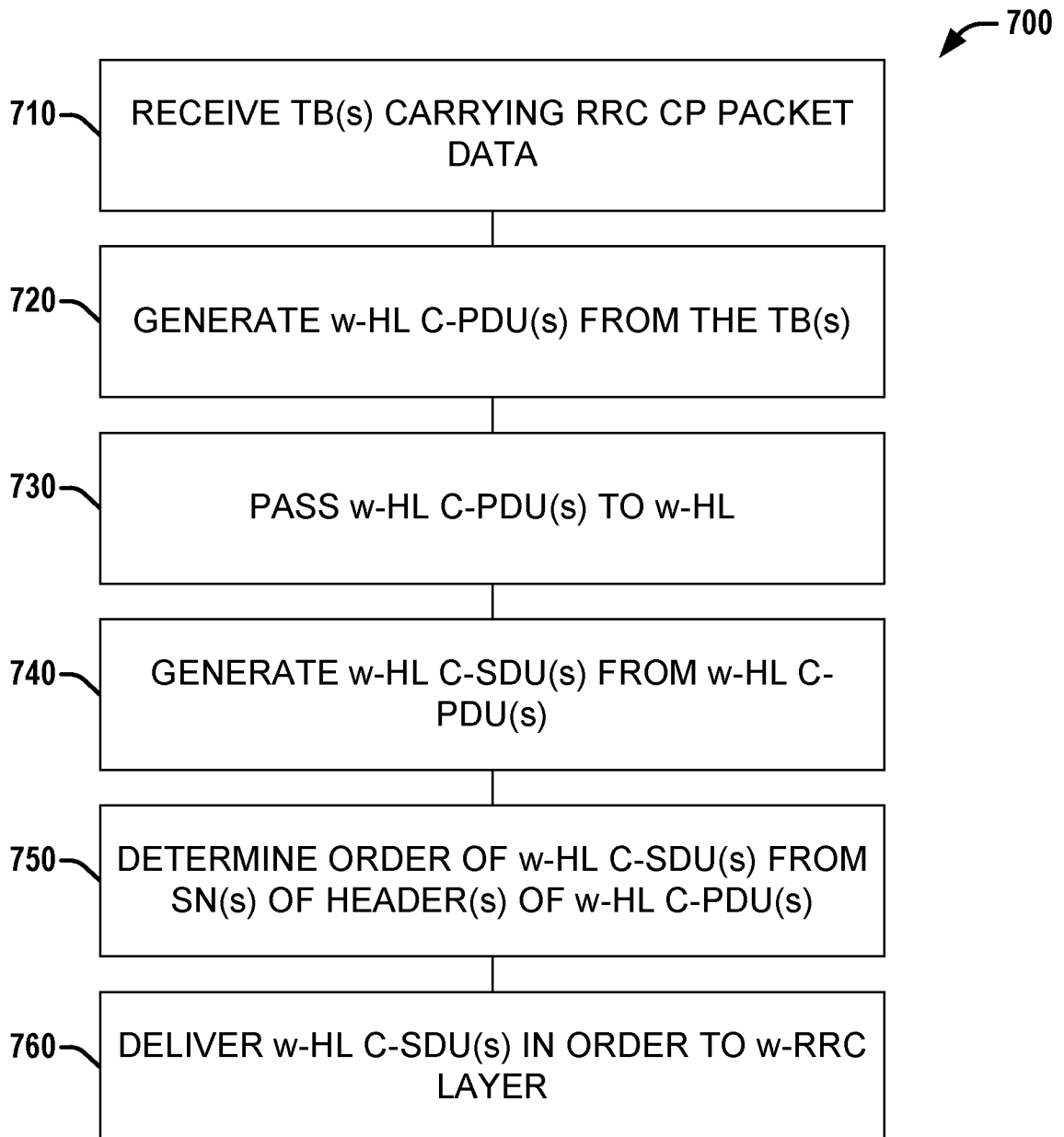


FIG. 7

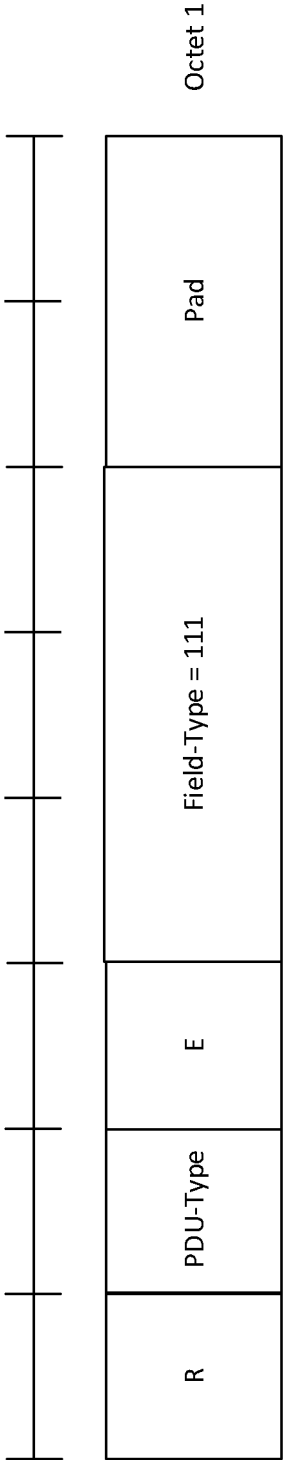


FIG. 8A

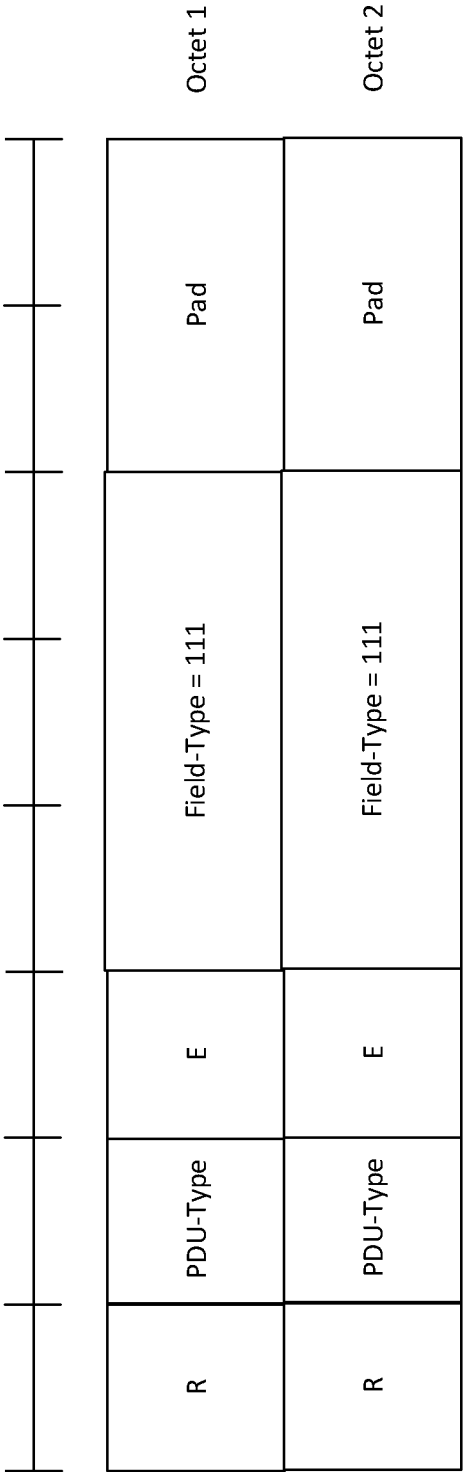


FIG. 8B

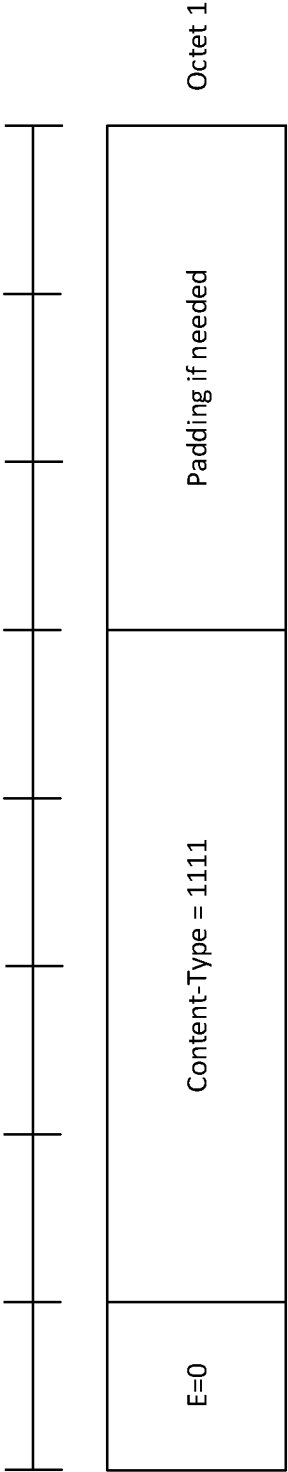


FIG. 8C

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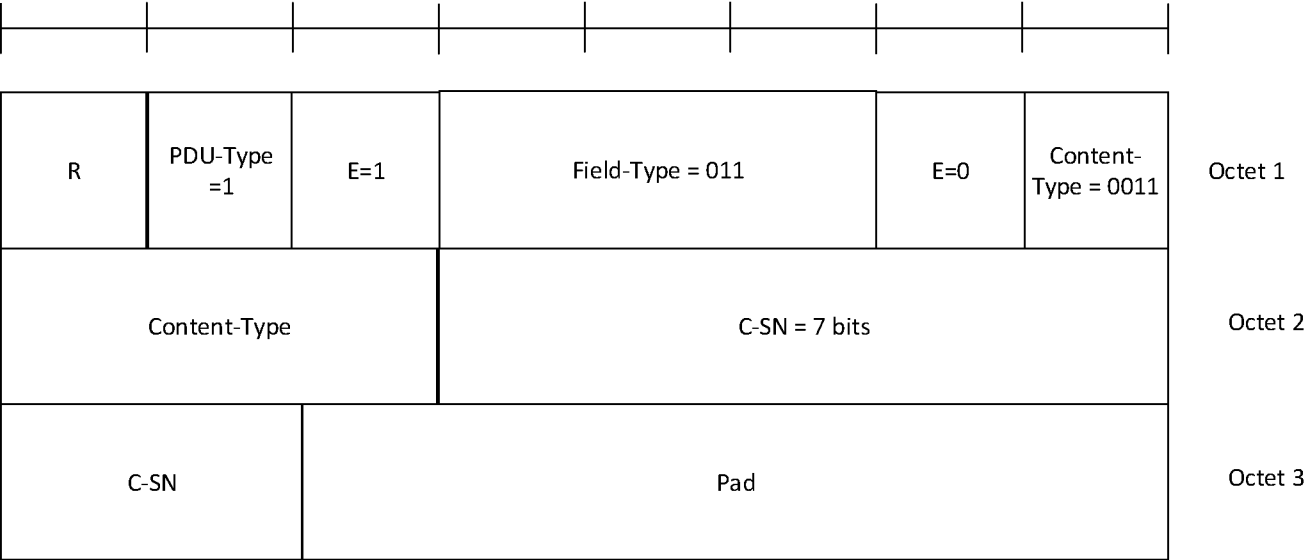


FIG. 9A

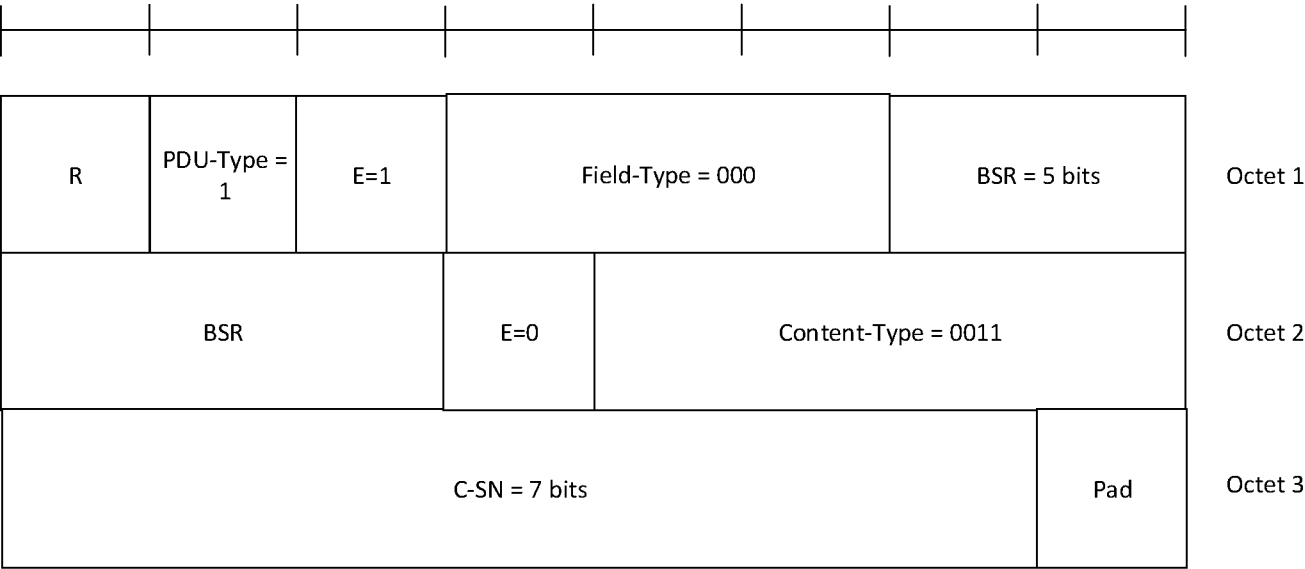


FIG. 9B

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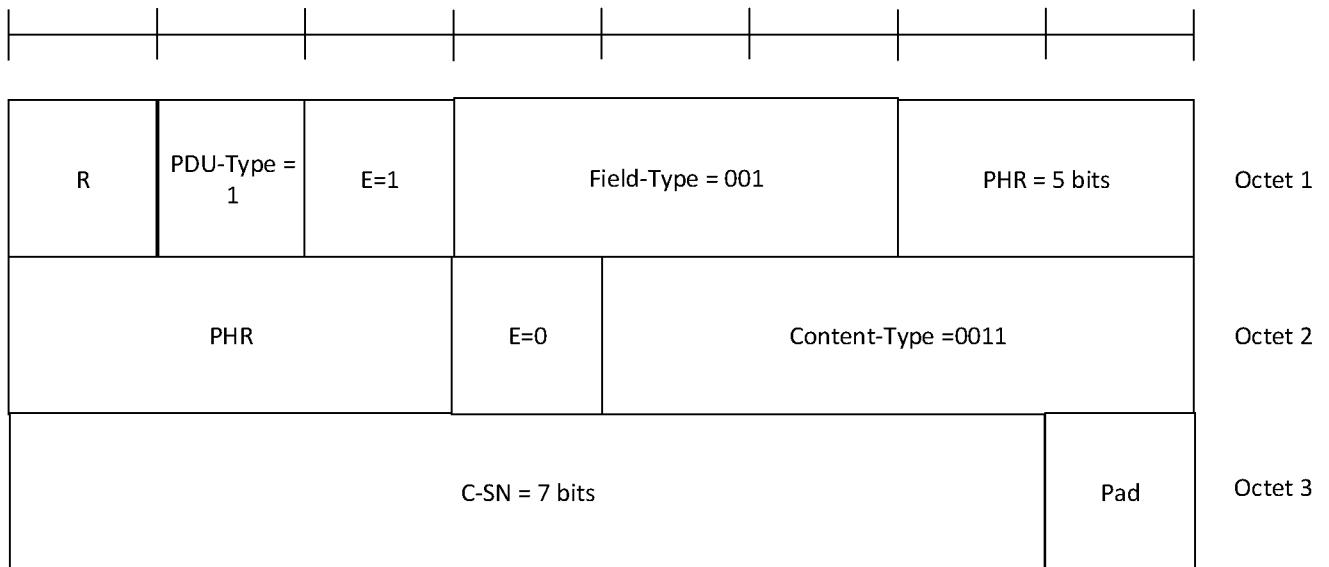


FIG. 10A

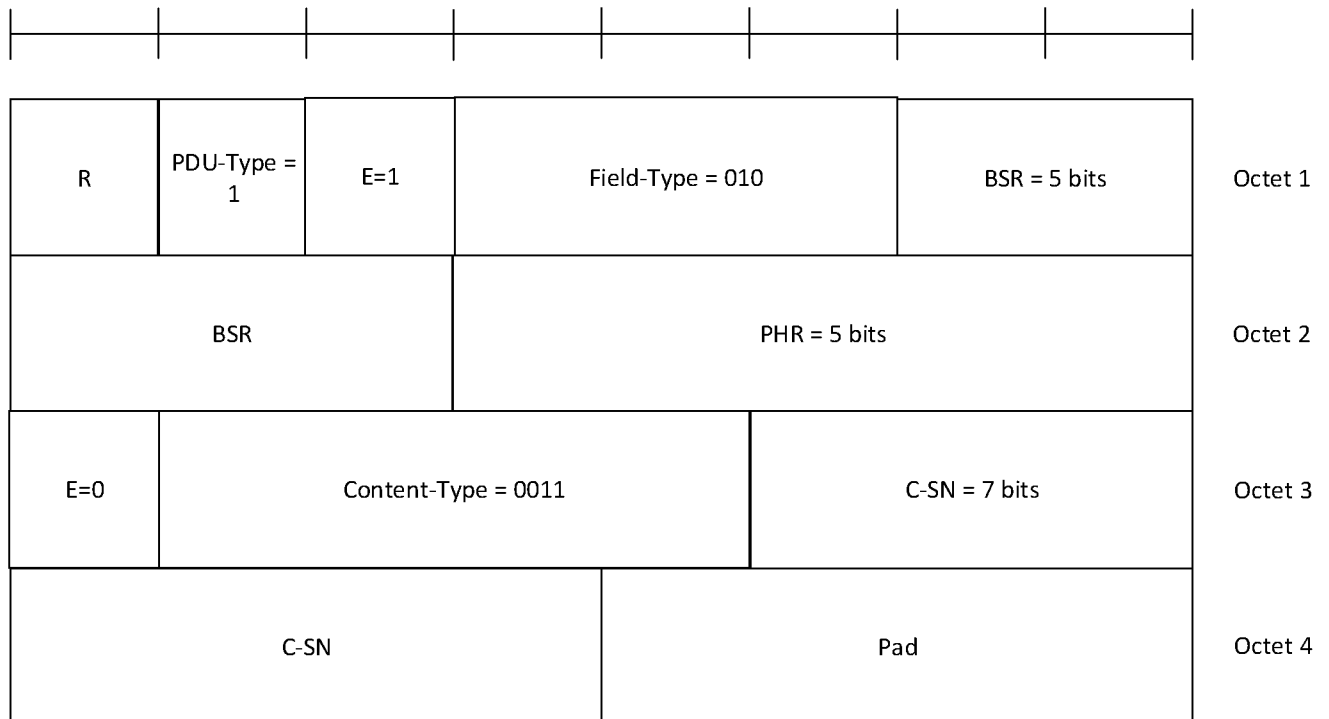


FIG. 10B

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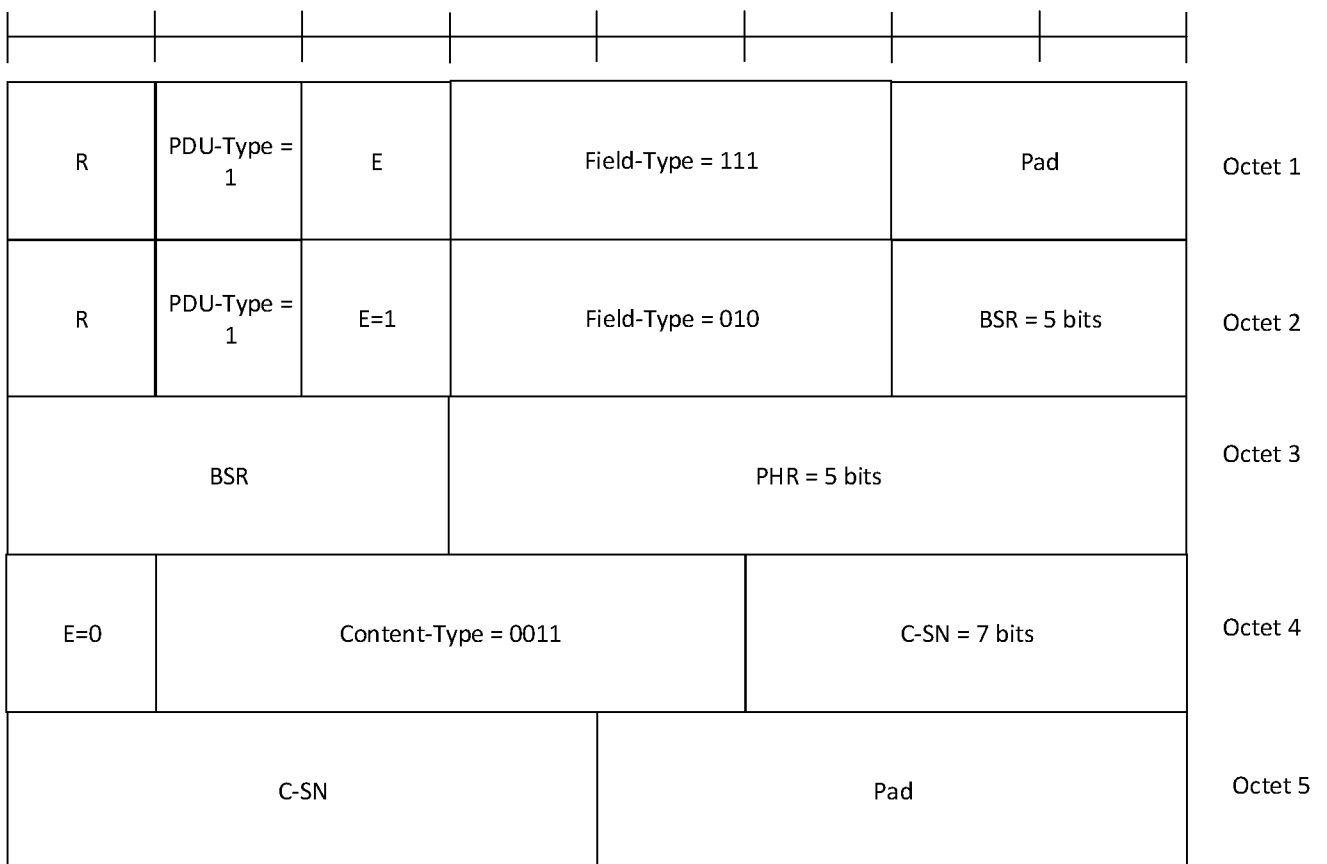


FIG. 11

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R	PDU-Type = 1	E	Field-Type = 111		Pad		Octet 1
R	PDU-Type = 1	E	Field-Type = 111		Pad		Octet 2
R	PDU-Type = 1	E=1	Field-Type = 010		BSR = 5 bits		Octet 3
BSR			PHR = 5 bits				Octet 4
E=0	Content-Type = 0011			C-SN = 7 bits			Octet 5
C-SN				Pad			Octet 6

FIG. 12

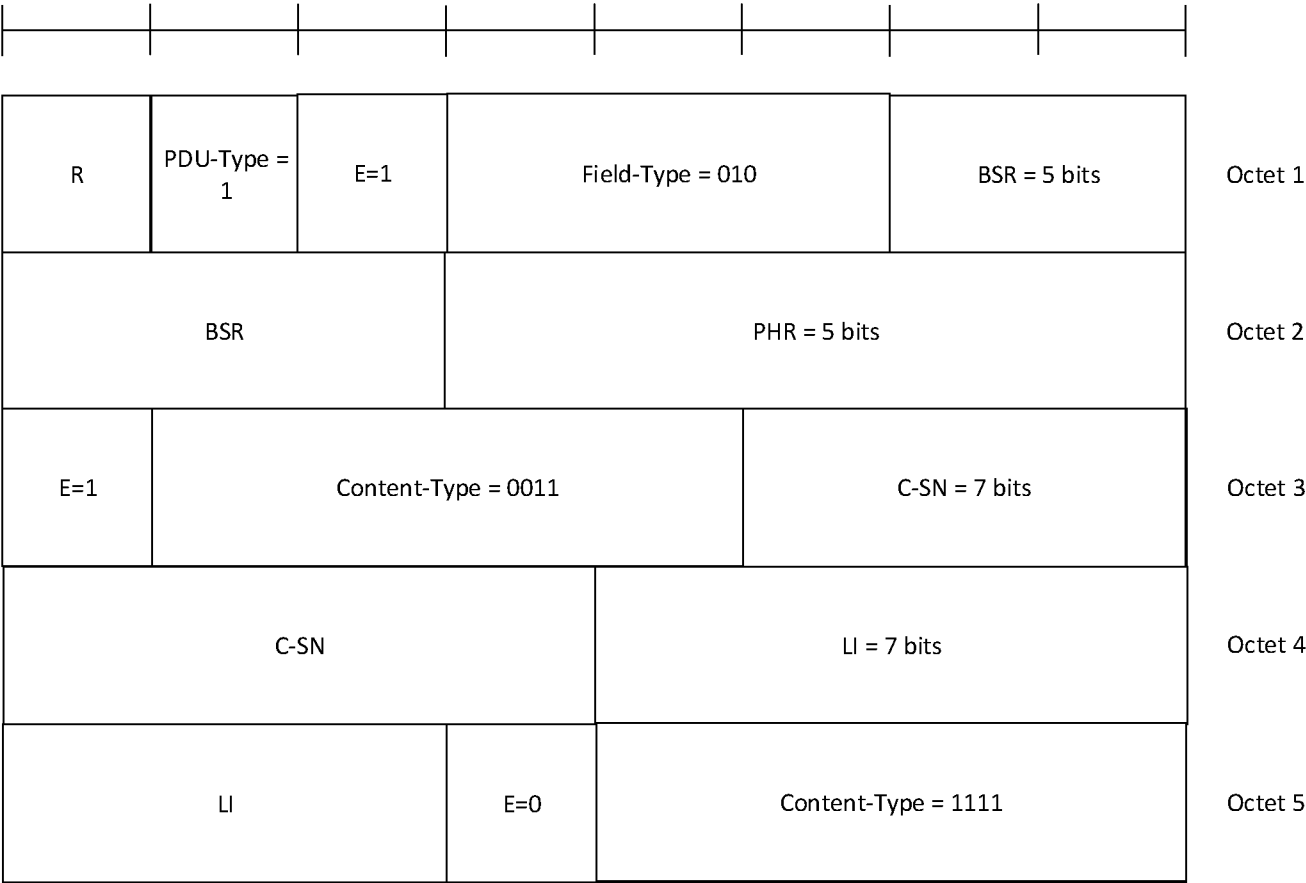


FIG. 13

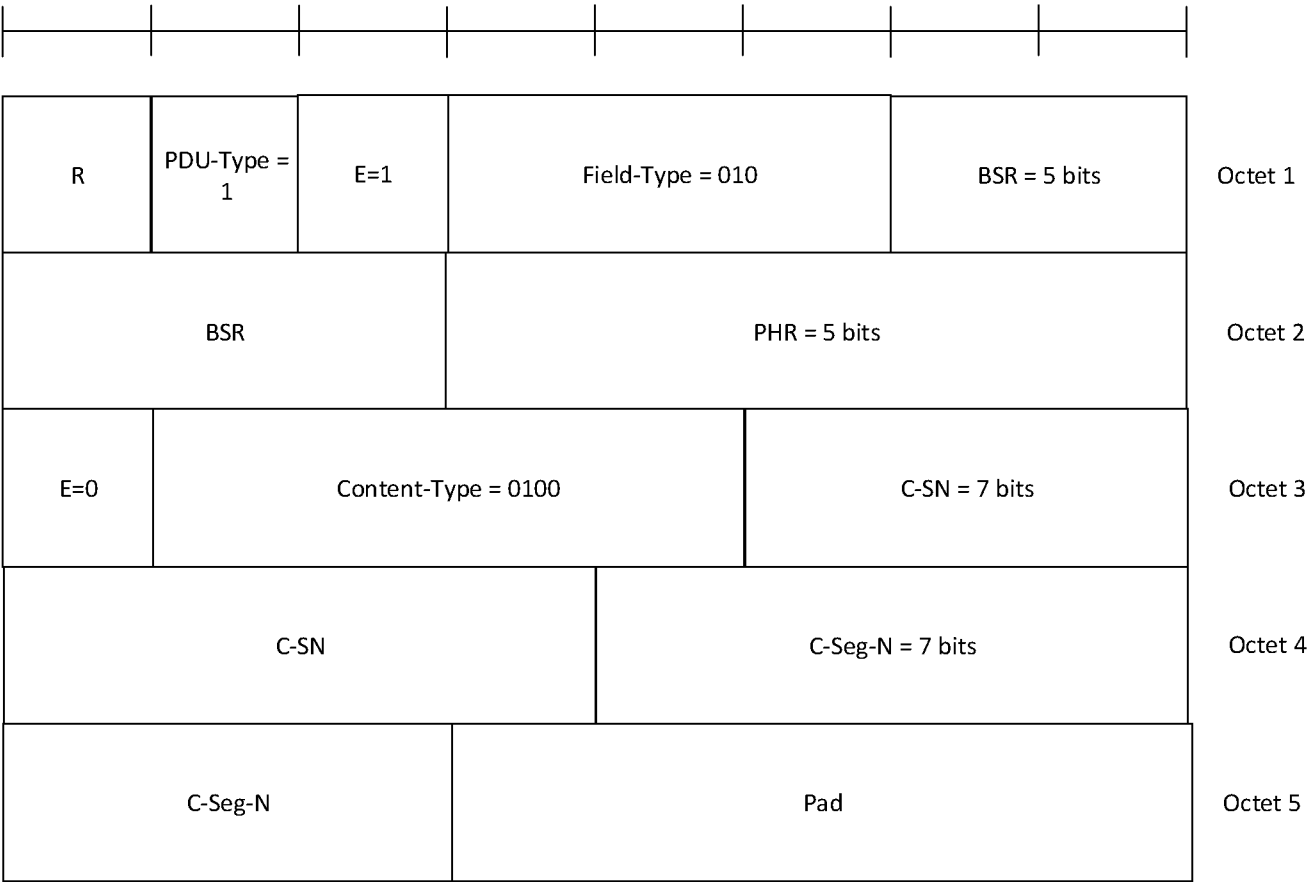


FIG. 14

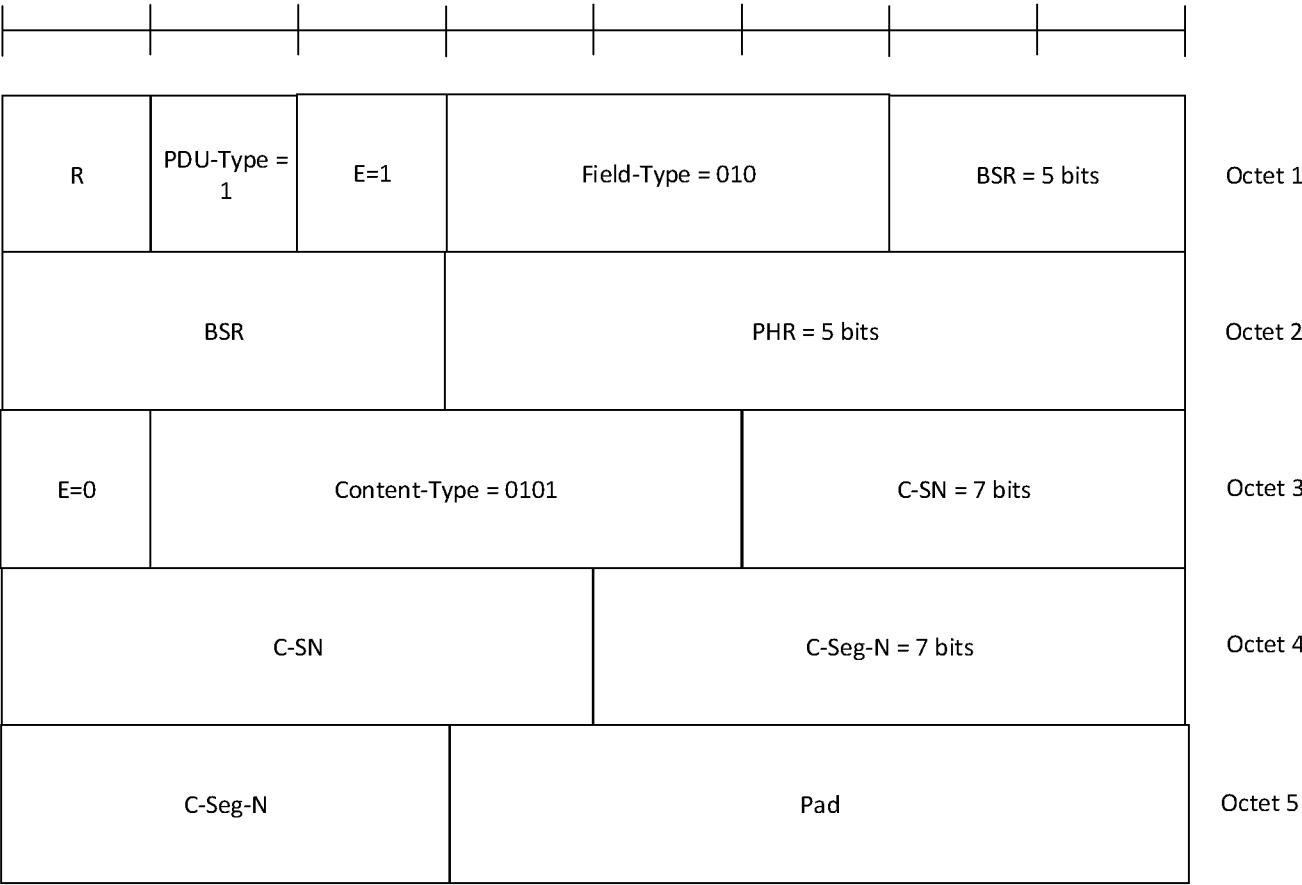
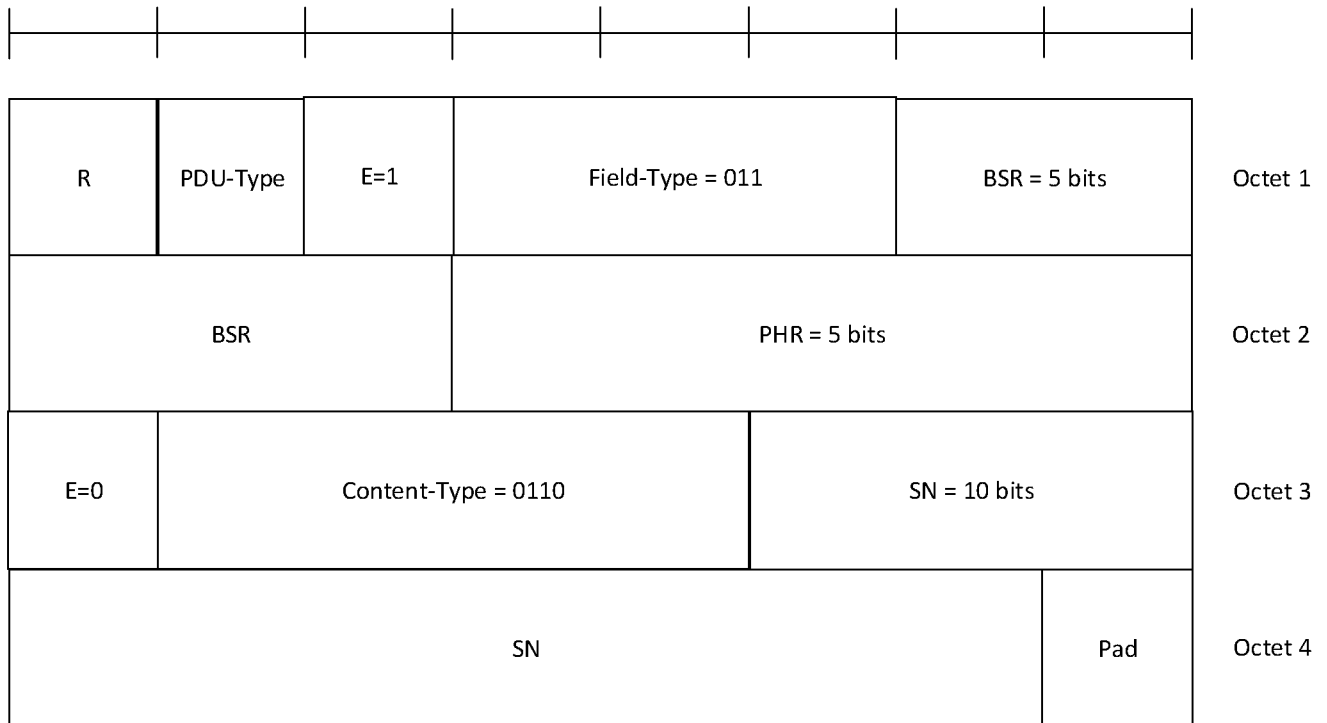
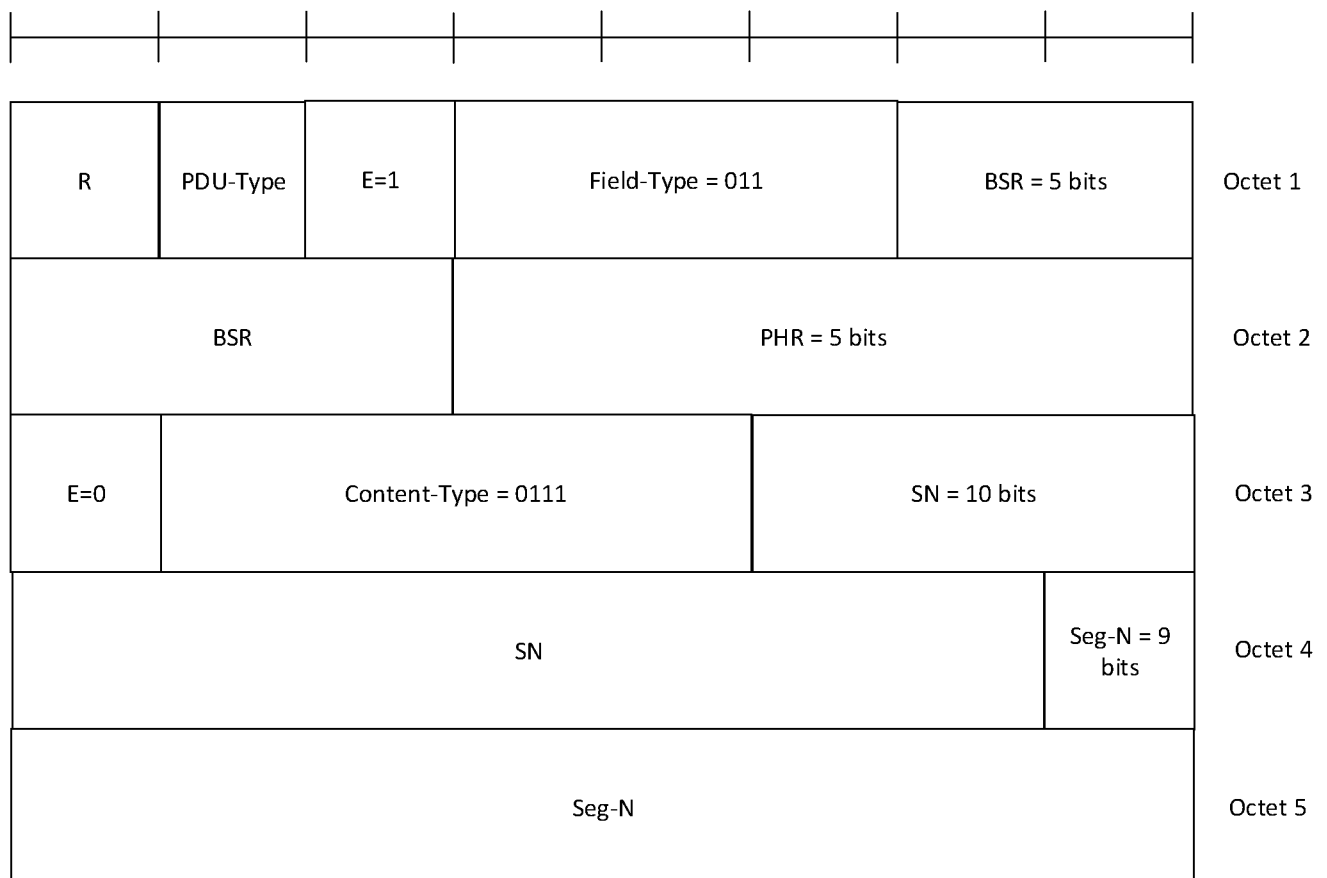
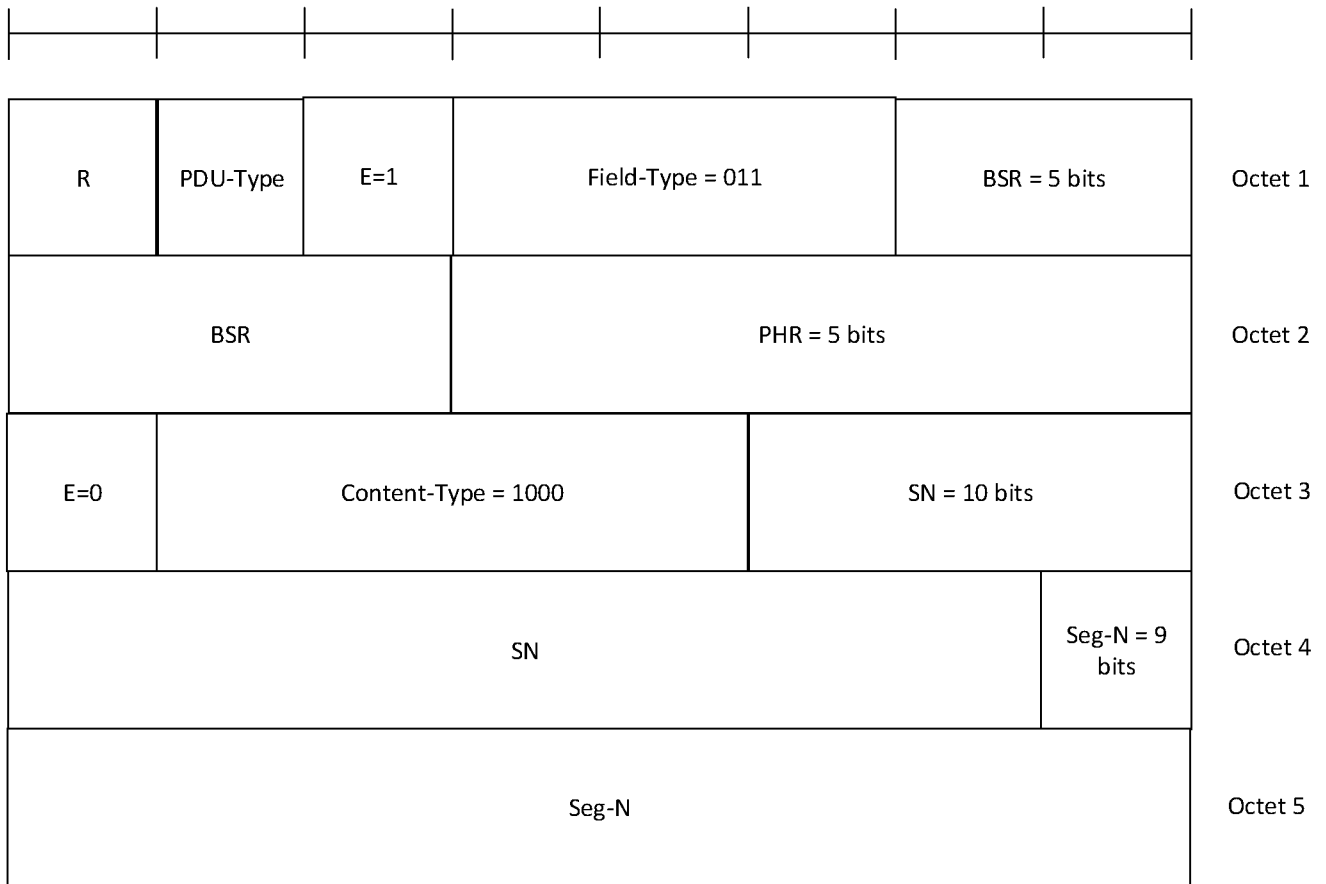
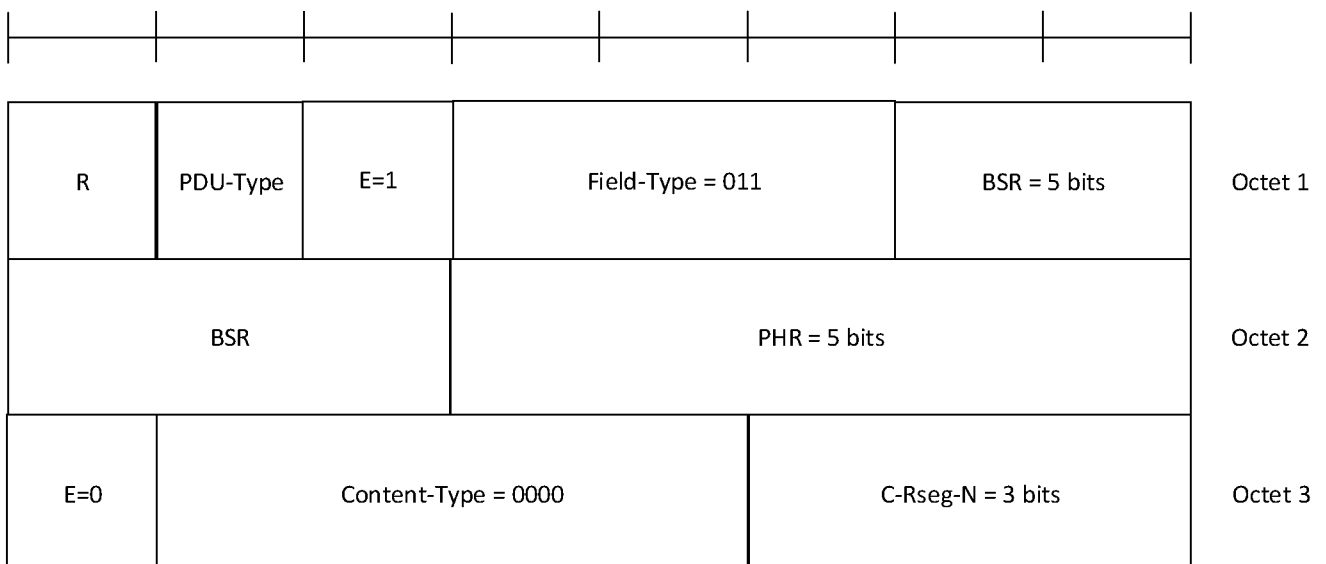


FIG. 15

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**FIG. 16A****FIG. 16B**

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**FIG. 17A****FIG. 17B**

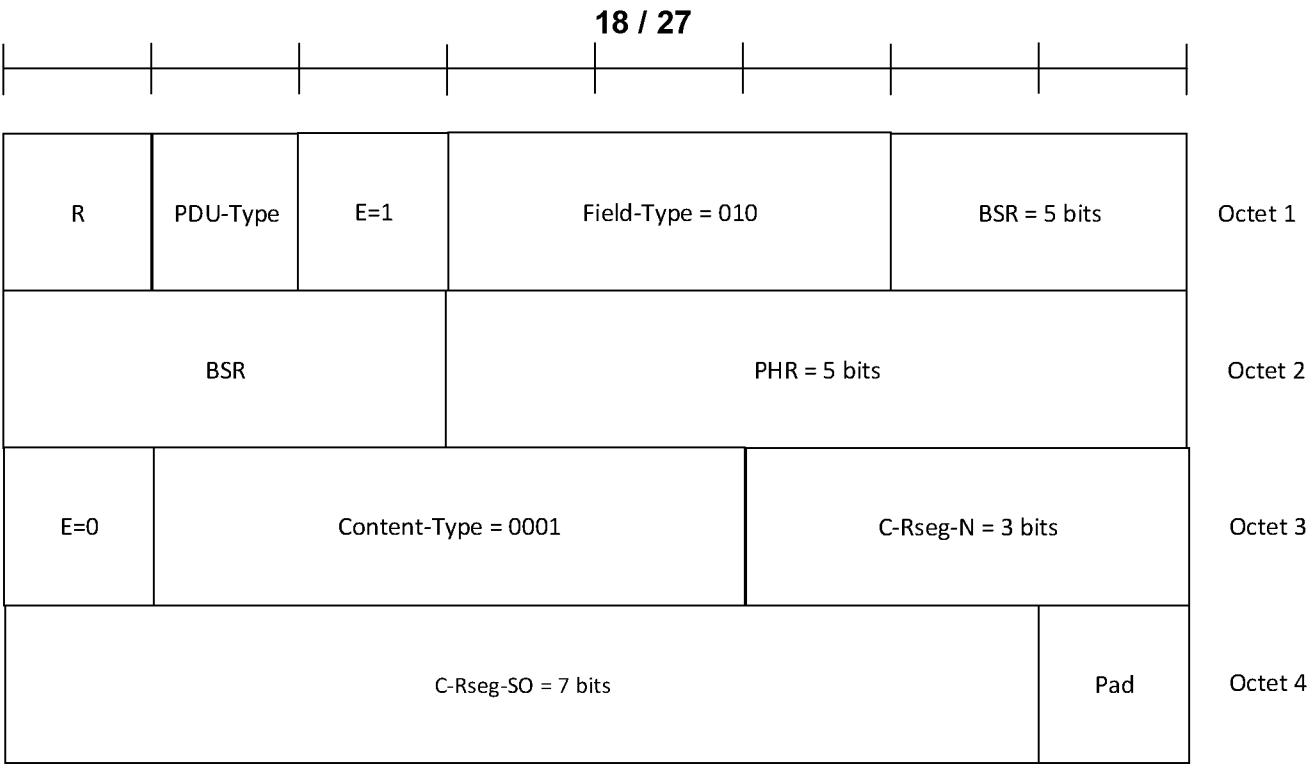


FIG. 18A

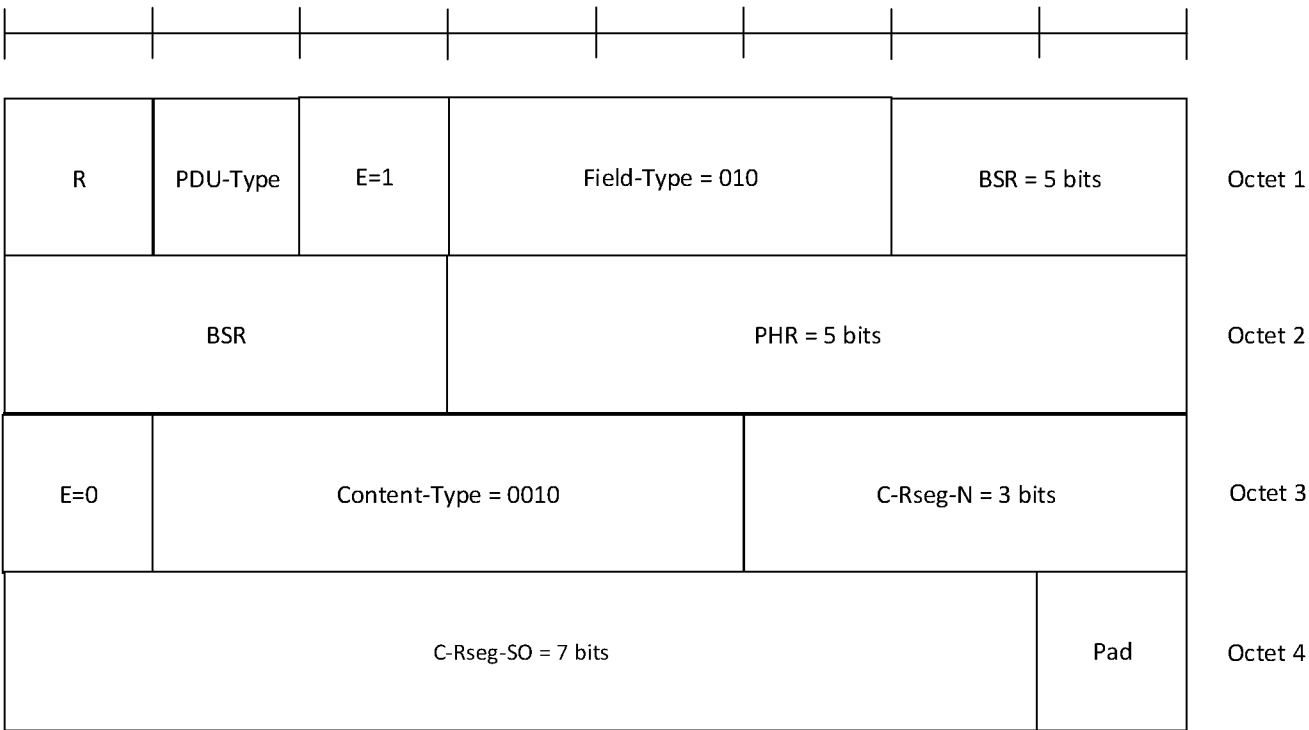


FIG. 18B

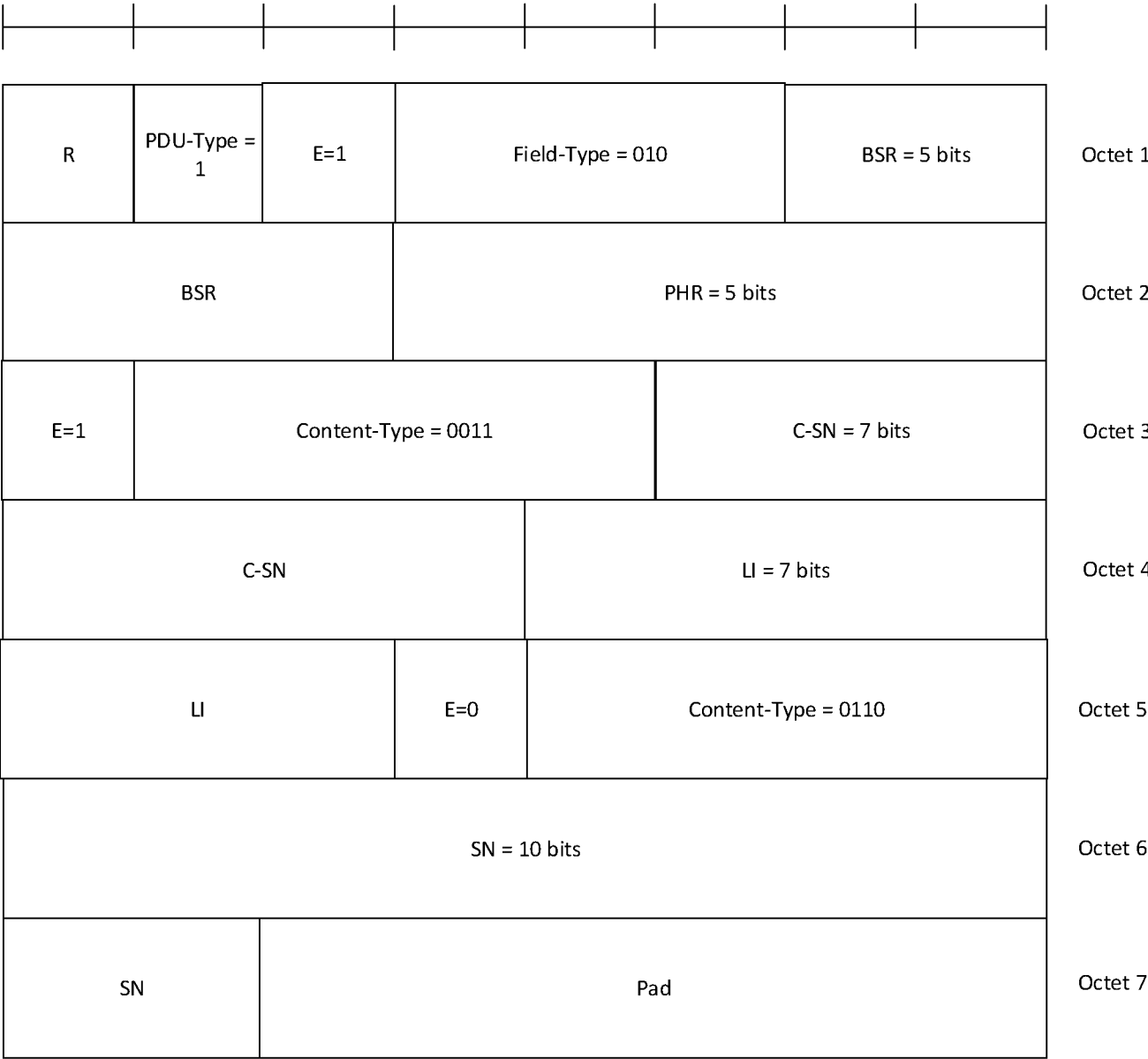


FIG. 19

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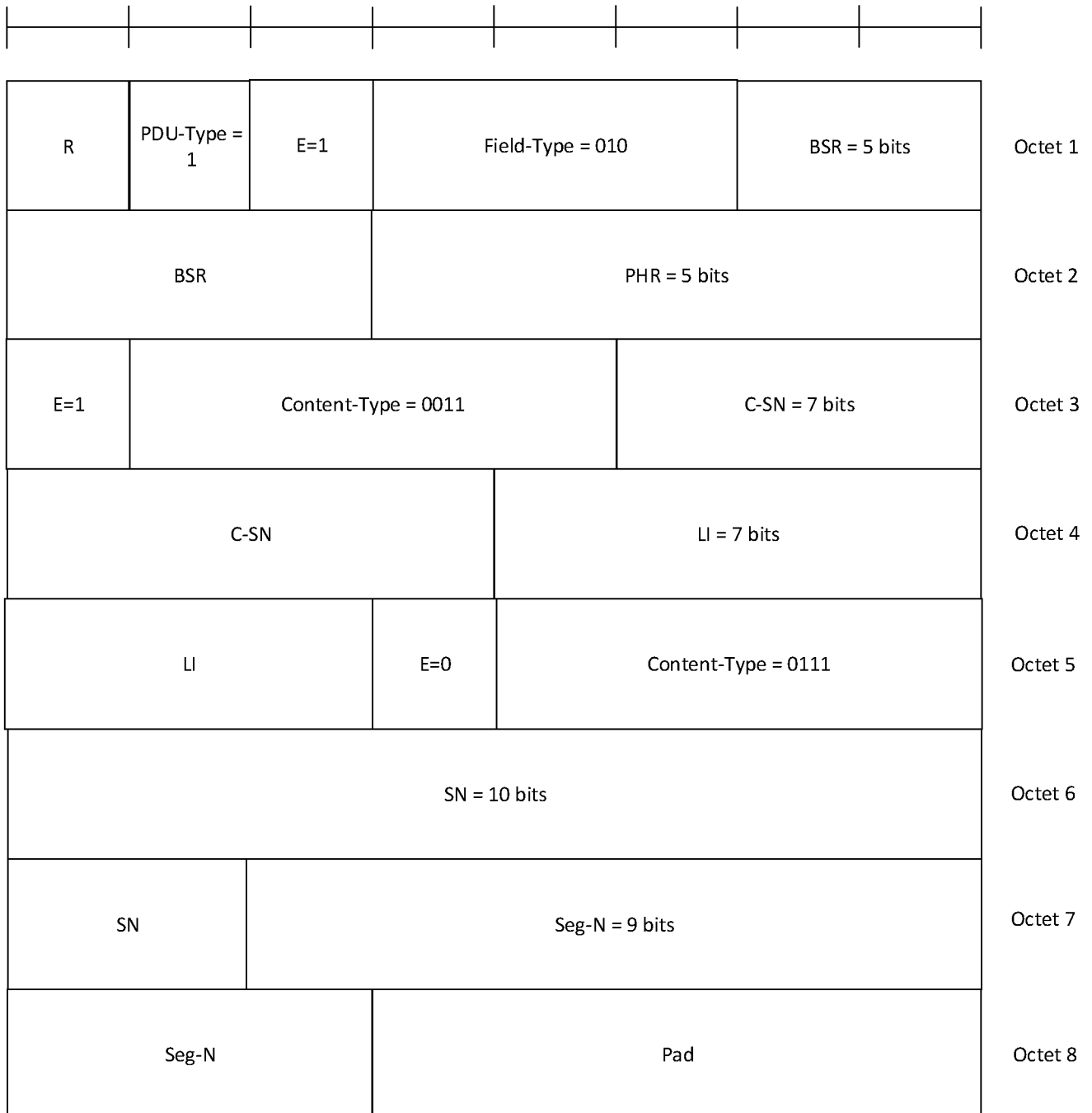


FIG. 20

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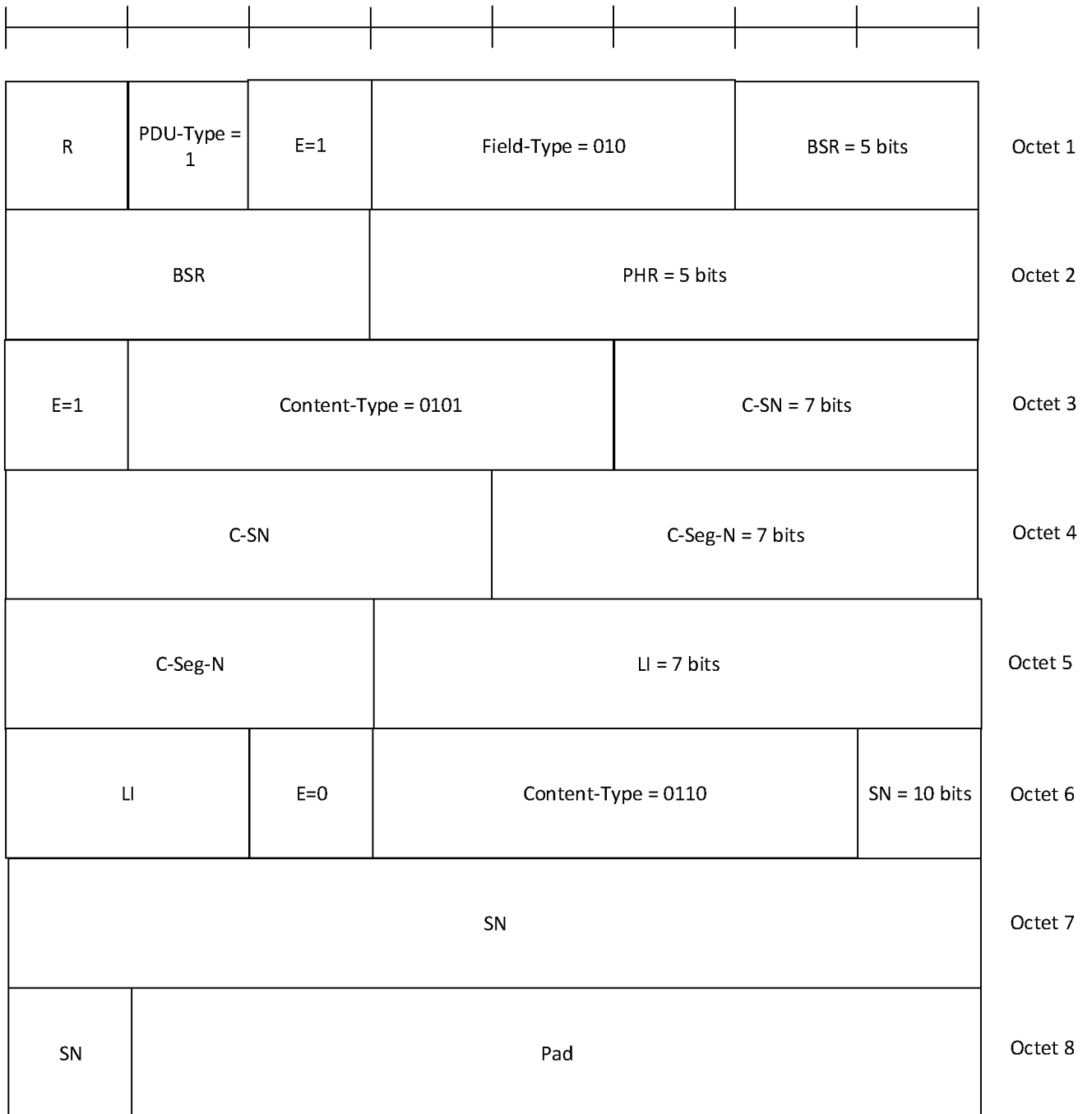


FIG. 21

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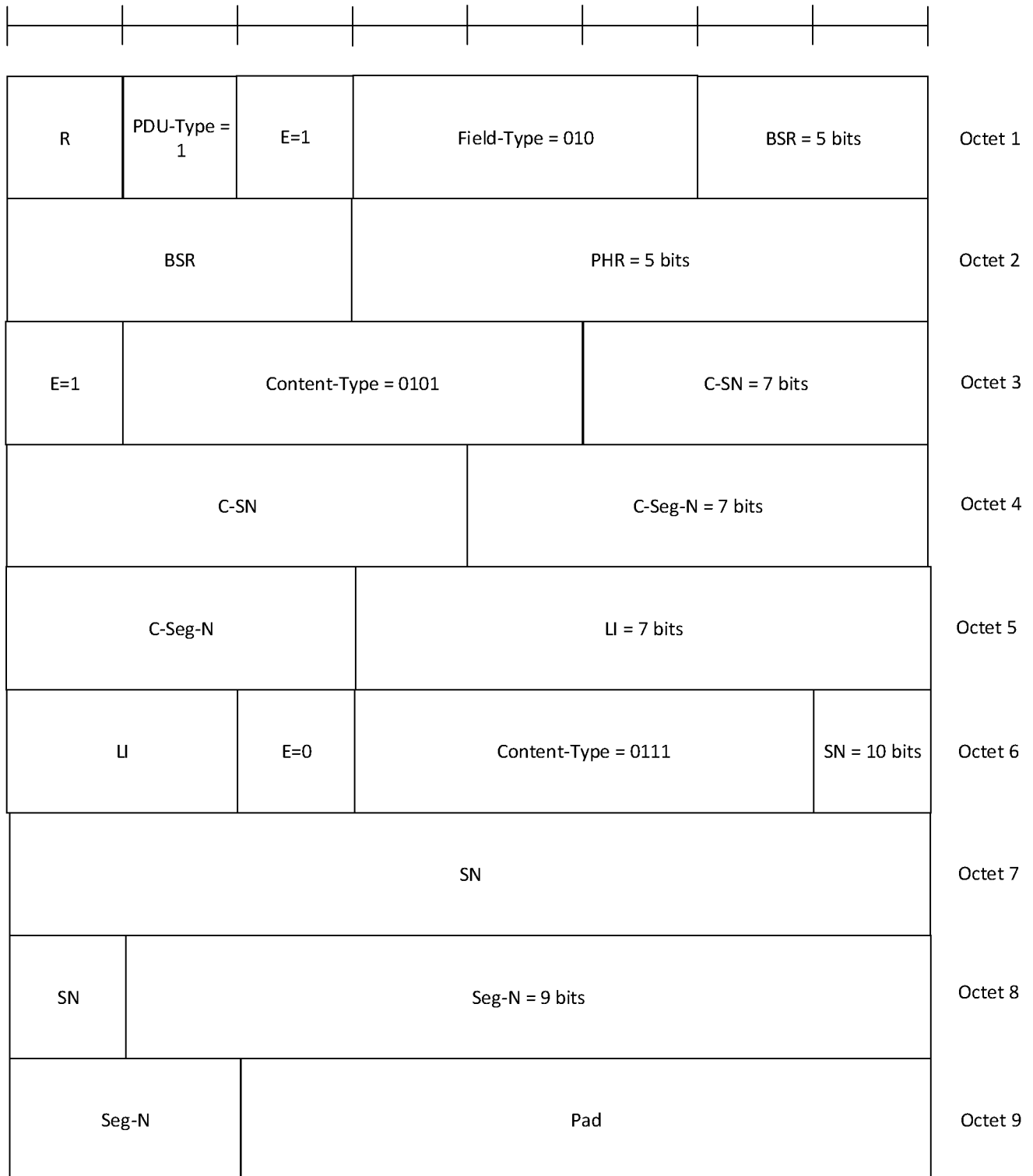


FIG. 22

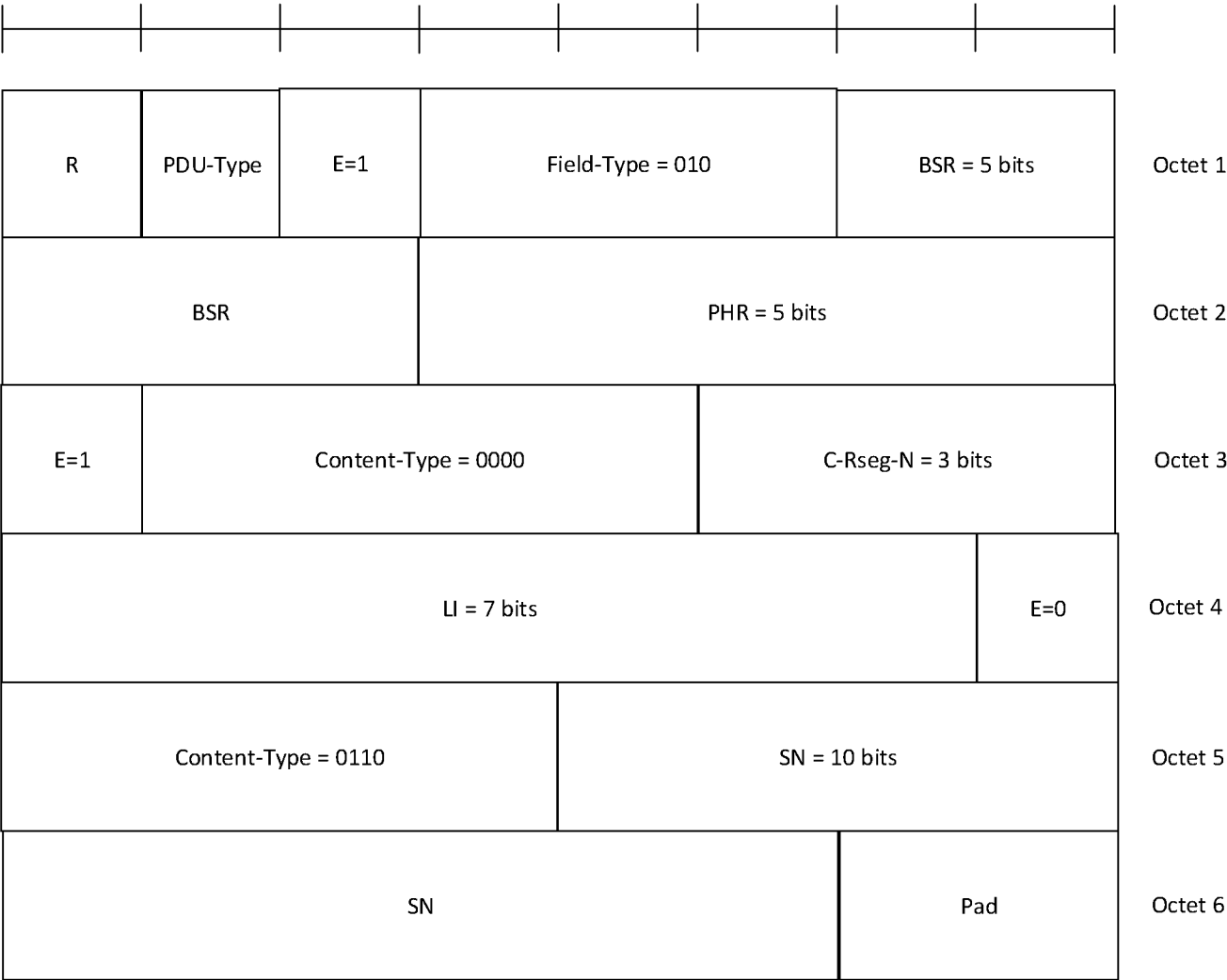


FIG. 23

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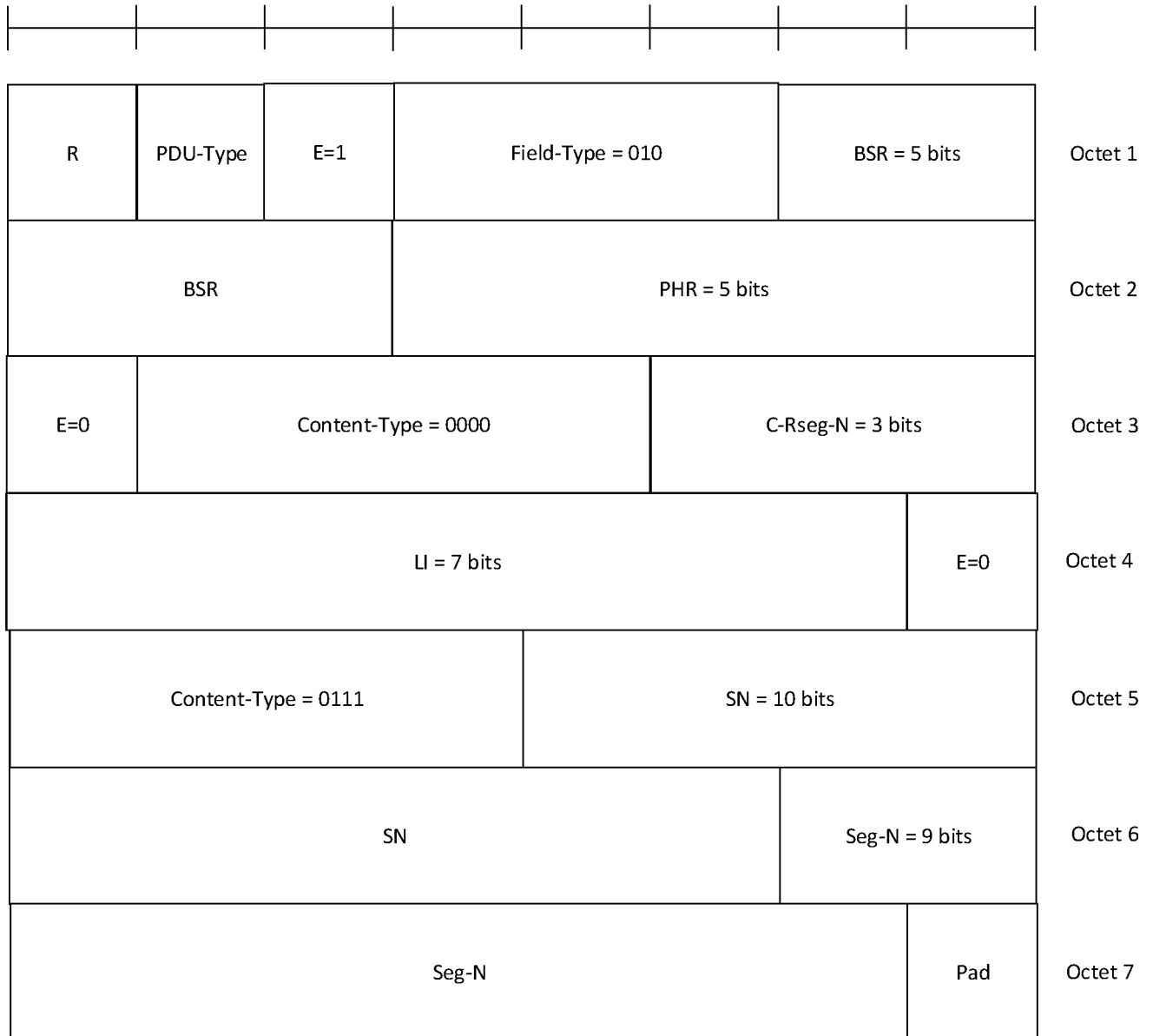


FIG. 24

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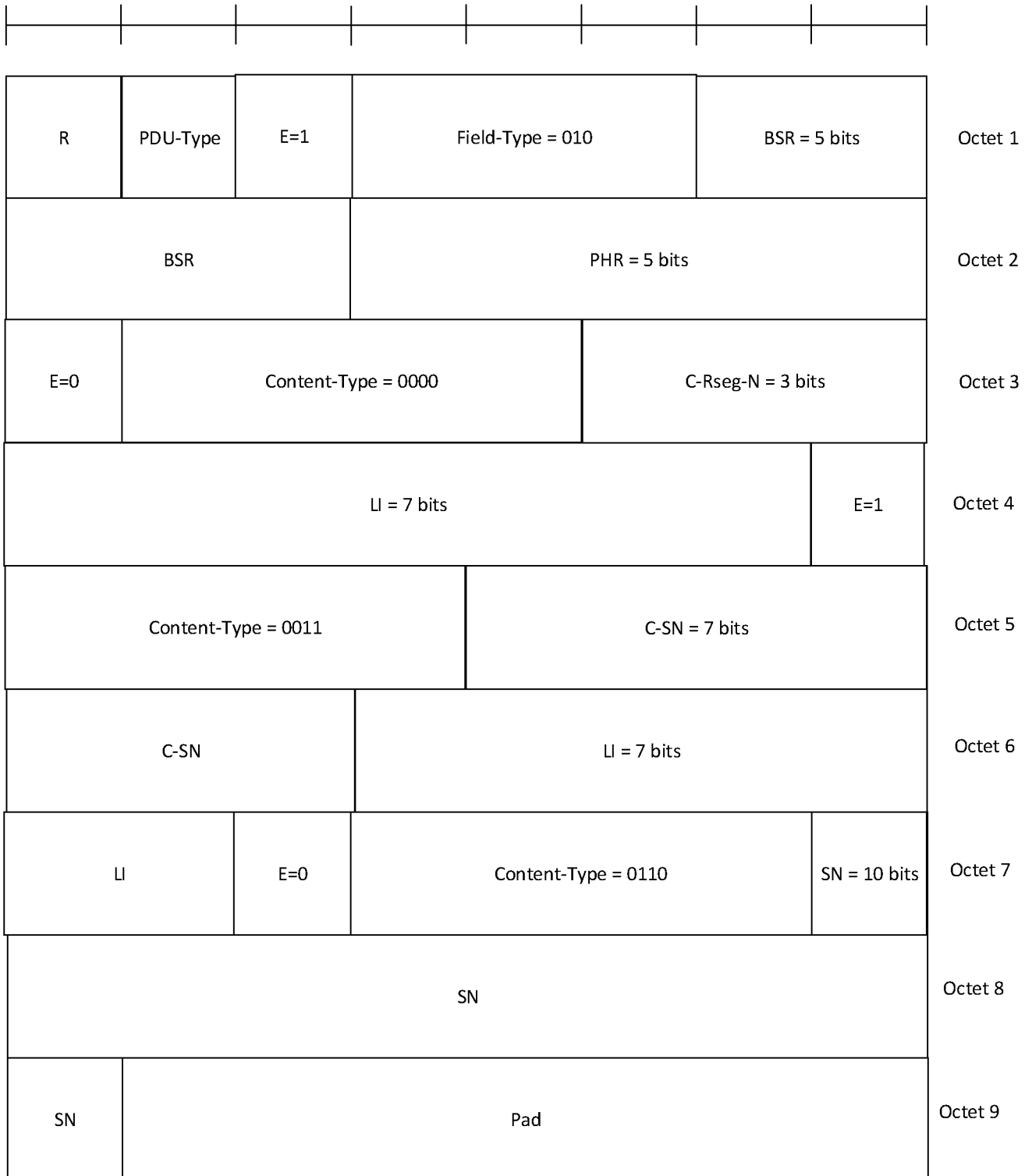


FIG. 25

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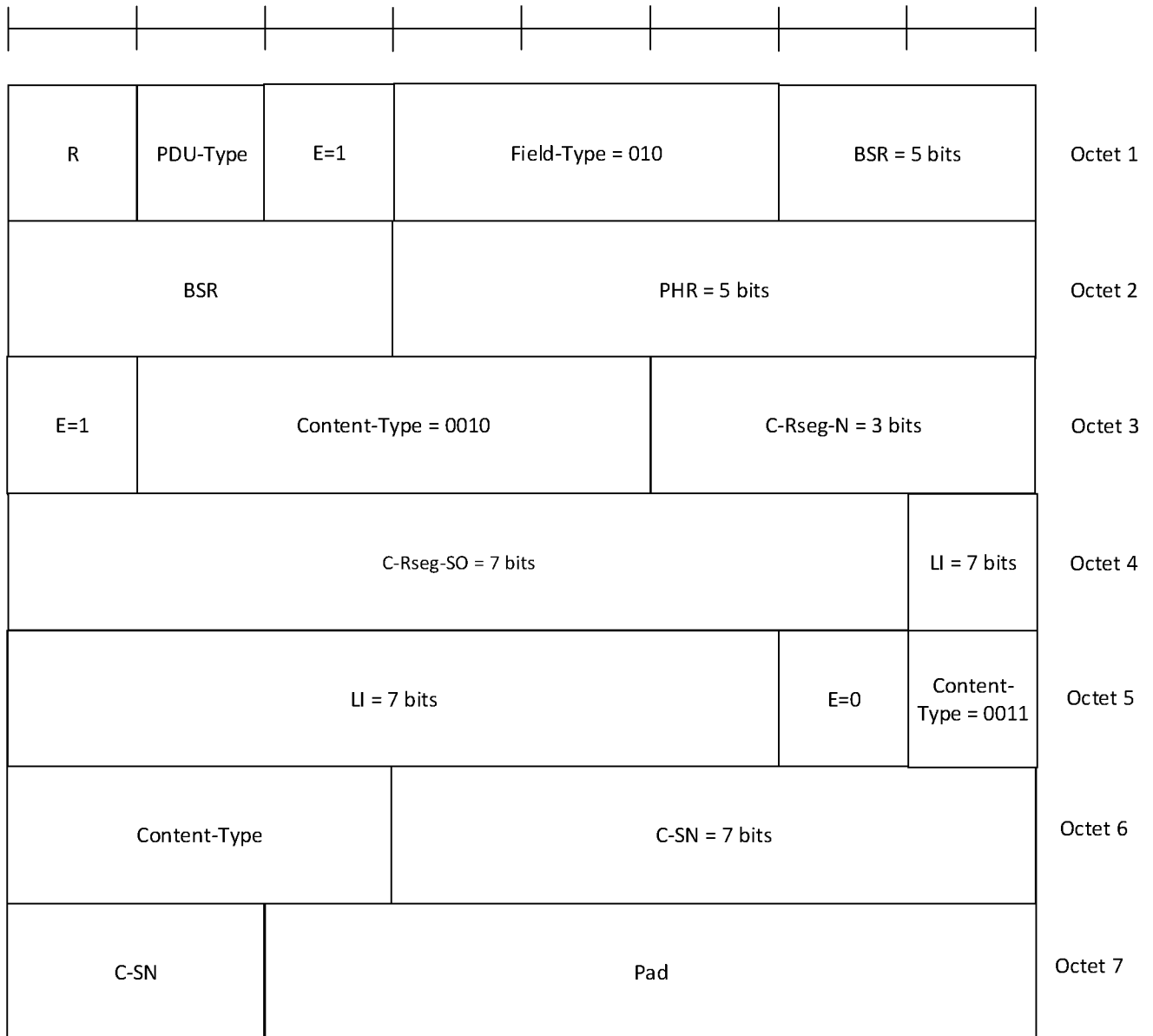


FIG. 26

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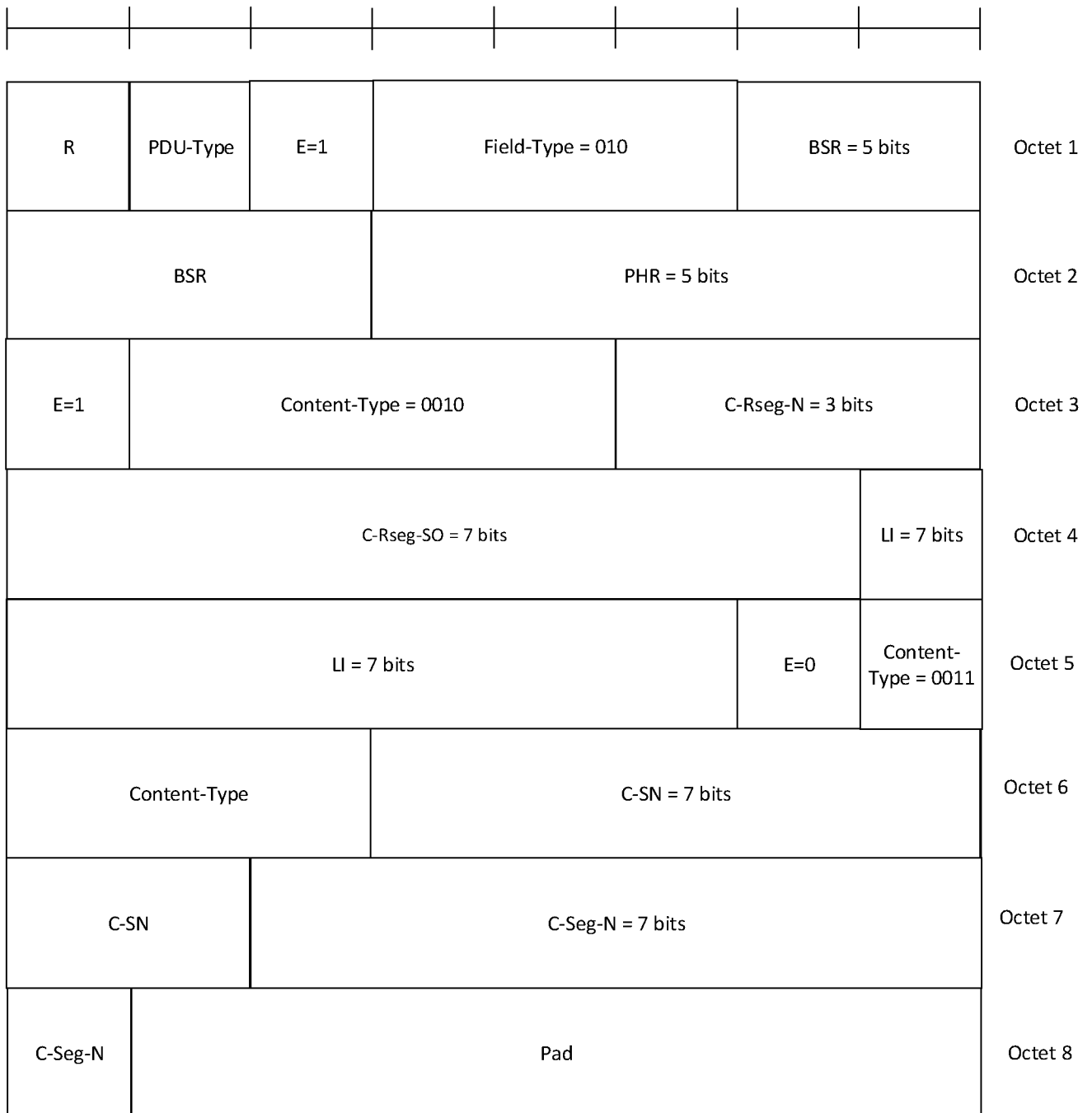


FIG. 27

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/053024

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W72/12 H04L29/08 H04W28/06
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)

H04W H04L

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	KR 2009 0068317 A (LG ELECTRONICS INC [KR]) 26 June 2009 (2009-06-26)	1,7,8, 10-17, 19-23, 25,26
Y	paragraphs [0005], [0007], [0009], [0014], [0024], [0028], [0031] - [0032], [0034], [0037] - [0038], [0040], [0055] paragraphs [0091], [0101] figures 2, 10, 13 ----- -/--	2-6,9, 18,24



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

15 February 2017

Date of mailing of the international search report

23/02/2017

Name and mailing address of the ISA/

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Metozoneve, Emeline

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/053024

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/053024

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