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(54) Title: PHYSICAL LAYER PROTOCOL AND SELF-CONTAINED SUBFRAME STRUCTURE FOR 5G/LTE COMPLIANT WEARABLE USER EQUIPMENT DEVICES

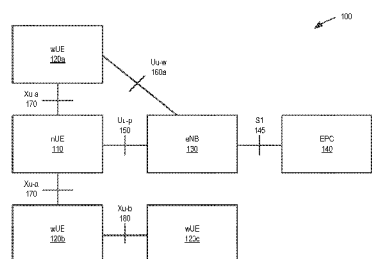


FIG. 1

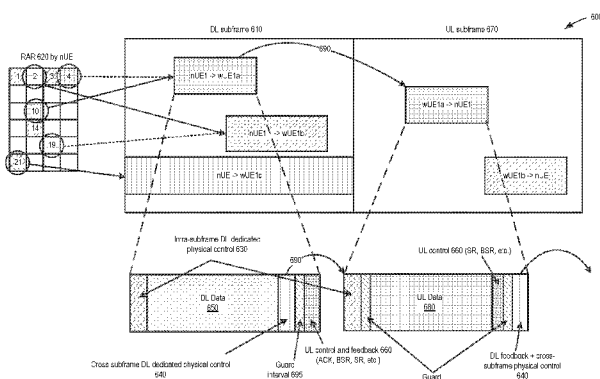


FIG. 6

(57) Abstract: This disclosure describes frame structures and layer one (L1) procedures suitable for Xu air interfaces. Features of the design are designed for energy-efficient operation and to meet other performance specifications and characteristics of ultra-dense user equipment deployments.



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PHYSICAL LAYER PROTOCOL AND SELF-CONTAINED SUBFRAME STRUCTURE FOR 5G/LTE COMPLIANT WEARABLE USER EQUIPMENT DEVICES

RELATED APPLICATION

[0001] This application claims benefit of U.S. Provisional Patent Application No. 62/300,335, filed February 26, 2016, which is hereby incorporated by reference herein in its entirety.

TECHNICAL FIELD

[0002] This disclosure relates generally to communication systems supporting wearable user equipment (UE) devices, and, more specifically, to an interface layer-one (L1) procedure and radio frame and subframe structures for allocating physical resources between wearable user equipment (wUE) devices (or simply, wUEs) and network UEs (nUEs).

BACKGROUND INFORMATION

[0003] Some devices currently use Bluetooth®, Bluetooth® Low Energy (Bluetooth® LE, BLE, marketed as Bluetooth® Smart), or other short-range wireless personal area network technologies for exchanging data over short distances. Bluetooth®, however, is limited to a three megabit per second (Mbit/s) over-the-air data rate and exhibits poor performance in ultra-dense deployments characterized by many devices communicating in a relatively small area (e.g., a subway). Other wireless local area networking (WLAN) technologies, such as Wi-Fi®, consume relatively high amounts of power that may not be available in mobile devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. 1 is a block diagram of a system architecture for supporting wUEs in communication with an nUE through an Xu-a air interface.

[0005] FIG. 2 is a sequence diagram of an Xu-a communication procedure.

[0006] FIG. 3 is a timing diagram of logical multiplexing of physical channels.

[0007] FIG. 4 is a block diagram of synchronization propagation within one synchronization cluster.

[0008] FIG. 5 is a block diagram of a random access (RA) and random access response (RAR) resource partition.

[0009] FIG. 6 is a block diagram of downlink (DL) and uplink (UL) resource allocation and physical channels including control and data channels.

[0010] FIG. 7 is a block diagram illustrating electronic device circuitry that may be UE circuitry, evolved universal terrestrial access network (EUTRAN) Node B (evolved Node B, eNodeB, or eNB) circuitry, network node circuitry, or other types of circuitry, according to one embodiment.

[0011] FIG. 8 is a block diagram illustrating components of a UE device according to one embodiment.

[0012] FIG. 9 is a block diagram illustrating components according to some embodiments.

[0013] Aspects and advantages will be apparent from the following detailed description of embodiments, which proceeds with reference to the accompanying drawings.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] FIG. 1 shows a communication system 100 for supporting wUEs. Entities of the system 100 include an nUE 110 having a full infrastructure network-access protocol stack (i.e., for full control- and user-plane functions); several wUEs 120 (e.g., 120a, 120b, and 120c) lacking standalone network-access connections but instead achieving network-access through, and coordinated by, the nUE 110; a EUTRAN Node B (eNB) (or more generally, a base station) 130; and an evolved packet core (EPC) 140. The nUE 110 and one or more of the wUEs 120 mutually authenticate to form a personal area network (PAN).

[0015] Air interfaces between the entities include an S1 interface 145 between the EPC 140 and the eNB 130; a Uu-p interface 150 between the nUE 110 and the eNB 130; a (higher power-demand) Uu-w interface 160a between the wUE 120a and the eNB 130 (similar Uu-w interfaces are not shown for the wUE 120b and the wUE 120c); Xu-a interfaces 170 between the nUE 110 and the wUE 120a and the wUE 120b; and an Xu-b interface 180 between the wUE 120b and the wUE 120c (other Xu-b interfaces are not shown). In general, the Xu-a interfaces provide intra-PAN air interfaces between an nUE and associated wUEs, and the Xu-b interfaces provide intra-PAN air interfaces among wUEs, but design principles described herein may apply to either of the Xu-a or Xu-b interfaces (generally referred to as Xu interfaces).

[0016] The described Xu interfaces and associated L1 procedures are designed for energy-efficient operation and to meet other performance specifications and characteristics of ultra-dense deployments. For example, with respect to the Xu-a and Xu-b interfaces, a typical transmission power may be of 0 dBm or less, and the

power consumption of the baseband modem constitutes a primary portion of total power consumption. To provide for power-efficient baseband operation and other design considerations, the following aspects are contemplated in the design of the Xu interfaces and L1 procedures: low baseband computation complexity; a baseband or core processor that is placed in an idle state as much as possible; ultra-dense deployment scenarios; uplink (UL) and downlink (DL) resource acquisition and utilization fairness among various UEs; and scalability from small to large networks.

[0017] Based on the aforementioned design considerations, this disclosure describes frame structures and L1 procedures suitable for the Xu interface(s). Some features of the design are summarized as follows.

[0018] The design is wUE centric and includes a wUE-specific physical control and data channel to minimize wUE blind detection. In conventional LTE systems, blind detection is used because each base station provides a common control channel, and multiple UEs in the coverage region share that common resource. Accordingly, each UE blindly detects in that channel its own control resource, e.g., decoding all of the control channel. In the present disclosure, however, each wUE has its own control channel, which reduces wUE computation complexity in obtaining control channel information, thereby reducing wUE power consumption.

[0019] The design includes a self-contained frame structure. In other words, data is transmitted in one portion of a subframe and feedback, such as an acknowledgement (ACK) or negative ACK (NACK) feedback, is provided during another portion of the same subframe. Also, although each subframe includes uplink and downlink periods, the subframes are referred to as UL or DL subframes because DL subframes include physical resources for transmission of DL data from an nUE to a wUE and UL subframes include physical resources for transmission of UL data from a wUE to an nUE.

[0020] The design considers a rapid transition between active and idle/power saving states for power savings.

[0021] The design includes contention-based inter-PAN resource coordination for scalability. Resource allocation of each PAN is done by handshaking—i.e., no central resource allocation is used in some embodiments. Also, under the contention-based embodiments, there is an automatic backoff timer for obtaining resources after collision in, e.g., an ultra-dense deployment scenario.

[0022] Another aspect of the design includes allowing a base station to coordinate the resource allocation when the nUE or its associated PAN overlaps with coverage of the base station. In other words, the base station can help assign resources to one or more PANs. And the resources allocated to each PAN might be selected by the base station to avoid collisions.

[0023] In a dense scenario, there is an increased likelihood of collision between wUEs requesting resources. Accordingly, the design includes a backoff procedure for reducing subsequent collisions, e.g., a resource request and data rate backoff for improved PAN coexistence in a dense scenario.

L1 Procedure

[0024] FIG. 2 illustrates an L1 procedure 200 for establishing an Xu-a interface. When a wUE 210 turns on or otherwise becomes active for transmitting or receiving communications, it synchronizes with a synchronization source (SS) nUE 220 or with a donor nUE 230 of the wUE 210 (i.e., when the donor nUE 230 is itself acting as a synchronization source) and reads system information. After obtaining synchronization and receiving the system information, the wUE 210 sends an RA message in a selected block of resources in an RA channel. Upon receiving the RA, the donor nUE 230 responds with an RAR in a resource block (i.e., a group of resource elements defined by subcarriers and symbols) having a physical location in an RAR channel corresponding to that of the RA. Examples of the corresponding locations are shown in FIG. 5. Accordingly, the transmission of RAR is free from collisions.

[0025] To receive the RAR, the wUE monitors the location of the resource block it had used to send the RA. Therefore, blind detection at the wUE is avoided. In the RAR, a bitmap indicating the resource assignment for the data transmission of the wUE will be transmitted along with other information. The wUE can then proceed with DL/UL traffic in the scheduled resource(s).

[0026] FIG. 3 shows a timing diagram 300 of logical multiplexing of physical channels. Component physical channels in the Xu-a interface include: a physical synchronization channel 310; a physical broadcast channel 320; a physical RA channel 330; a physical RAR channel (optionally including paging and initial scheduling assignment (SA)) 340; a dedicated physical control channel 350; and a physical data channel 360.

[0027] The logical multiplexing shows that there are synchronization intervals 380 provided every radio frame. Within some synchronization intervals, there is a partly overlapping RA and paging interval 390.

Synchronization

[0028] Synchronization may be achieved by a single-frequency-network (SFN) type of synchronization, in which the nUEs and wUEs within one cluster (also called a synchronization cluster) are synchronized based on propagation of a single SS. A synchronization cluster may have multiple PANs. For example, a wUE may be in range of a first nUE but out of range of a second nUE, but the nUEs are still synchronized because they can hear each other's broadcast channel. Accordingly, all the nUEs and wUEs within a cluster are synchronized through a common synchronization channel. In other words, all the nUEs are broadcasting the same synchronization signal, which may comprise a sequence. And, in some embodiments deployed within a base station coverage region, the base station optionally maintains synchronization by providing, for example, primary/secondary synchronization signals (PSS/SSS). Because there is a common synchronization, the design may maintain a radio frame boundary aligned among the PANs for reduced collision avoidance.

[0029] FIG. 4 illustrates synchronization propagation within a cluster 400. The cluster includes eight nUEs 410, each of which maintains a PAN 420 including one or more wUEs 430 within the cluster 400. Two of the nUEs 410 are also acting as an SS 440, broadcasting a common synchronization signal at the same time so as to extend the coverage of the cluster 400.

[0030] An nUE becomes an SS by determining whether it satisfies certain criteria. The criteria can be based on: whether the nUE has residual power (e.g., battery power) available above a certain threshold and suitable for higher power SS transmissions; the received power of the synchronization signal at the nUE is below a certain threshold; or other criteria. When an nUE becomes an SS, it will begin transmitting the same synchronization signal as it received in the cluster.

System Broadcasting

[0031] The system information transmitted in the broadcasting channel may include the following information (and numbers of bits are also listed as examples): system bandwidth (3 bits); subframe number (10 bits); CRC (16 bits); in-coverage indicator (1 bit) indicating whether the cluster is in a base station coverage region for

accessing the core network; a bitmap for RA resource allocation; and RA configuration.

[0032] The bitmap for RA resource allocation may be a string of bits having binary values indicating whether a resource block corresponding to the bit location may be used for RA. Based on this information, the wUE will know the resource it can use for sending RA.

RA and RAR

[0033] Each of the wUEs seeking to perform RA randomly selects at least one resource block in the RA region and transmits an RA message for a particular donor nUE. The donor nUE identifies that the RA message is addressed to it, and responds to the wUE (and any other wUEs using different resource blocks) using the same location of the resource block that the wUE had used for transmitting the RA. When there is a successful reception of the RA from the wUE, the RAR from the nUE will be free from collisions.

[0034] FIG. 5 illustrates a pair of RA and RAR resource partition grids 500. Each block in a grid represents one resource block in the RA and RAR regions. When transmitting an RA, each wUE randomly picks one or more resource blocks from the RA partition grid. A total number of resource blocks each wUE may randomly select from the grid is predefined. Because each wUE randomly selects its resource blocks, there is some chance of collision between wUEs selecting the same block. But wUEs may take multiple blocks for transmitting redundant RA messages, which improve the likelihood that one of the blocks will not collide and that the nUE will receive at least one of the RA messages. In the example shown by blocks sharing a same type of shading in FIG. 5, each wUE takes two randomly selected resource blocks (e.g., block numbers 3 and 21, which share a type of crosshatch shading pattern). Also, when transmitting RA, power boosting can be applied when needed to ensure high access probability (e.g., initial access, high priority access).

[0035] The information contained in the RA may include (the number of bits are listed as examples): wearable RA radio network temporary identifier (w-RA-RNTI, 16 bits); wUE MAC address or other network identifier (48 bits, for first time access) or wearable cell radio network temporary identifier (w-C-RNTI, 16 bits, for idle wUE); or buffer status report (8 bits).

[0036] The RA preamble configuration could be common to all PANs in the cluster. This allows open-accessible nUEs to admit wUEs.

[0037] In the RAR, each of the corresponding donor nUEs responds to each of the wUEs by using resource blocks in the RAR grid having the same relative location as those used in the RA grid. For example, the nUE might receive one of the non-colliding messages from RA block number 3, and therefore the nUE provides the RAR in RAR block number 3.

[0038] The information contained in the RAR may include (the number of bits are listed as examples): w-RA-RNTI (16 bits); w-C-RNTI (16 bits); nUE id (10 bits); paging; or scheduling assignment in time and frequency (bitmap) for the first subframe of the dedicated control and data channel (13 bits + 7 bits).

Dedicated Physical Control Channel and Data Channel

[0039] FIG. 6 shows that, within resources 600 allocated to each of the wUEs, there are dedicated control and data channels. For a DL subframe 610, each wUE resource (previously allocated from RAR 620) contains two DL dedicated physical control channels 630 and 640, a DL data channel 650, and a UL control/feedback channel 660. The two DL dedicated physical control channels are referred to as the intra-subframe DL dedicated physical control channel 630 and the cross-subframe DL dedicated physical control channel 640. For the UL subframe 670, each subframe contains the DL control channels 630 and 640, a UL data channel 680, and the UL control channel 660.

[0040] The intra-subframe DL dedicated physical control channel 630 is used for intra-subframe transmission scheduling. This includes providing modulation coding scheme (MCS) index information and intra-PAN resource allocation by which to manage the transmission within the subframe, such as to indicate the transmission power level.

[0041] The cross-subframe DL dedicated physical control channel 640 is used for scheduling resources available in the next subframe. When accompanying the DL data channel 650, the control channel 640 indicates whether the subsequent subframe is a DL or UL subframe, and it indicates 690 a resource assignment for the wUE to use during that next subframe. When accompanying the UL data channel 680, the control channel 640 provides for feedback from the nUE to the wUE and for a scheduling assignment (SA) of the next subframe.

[0042] Each subframe is self-contained because it encompasses both communication (e.g., downlink) and feedback (e.g., uplink) periods at different times

in the subframe. Accordingly, one or more guard intervals 695 is inserted between DL/UL switches within a subframe.

[0043] The wUE dedicated physical channel design avoids blind detection at the wUE because each wUE has its own control resources. It is worth noting, however, that the wUE dedicated physical channel does not preclude other embodiments in which two or more wUEs share the physical channel. In such a case, some blind detection among the wUEs that share the same channel is performed.

Example Devices and Circuitry

[0044] FIG. 7 is a block diagram illustrating electronic device circuitry 700 that may be eNB circuitry, UE circuitry, network node circuitry, or some other type of circuitry in accordance with various embodiments. 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 executes 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.

[0045] In embodiments, the electronic device circuitry 700 may be, or may be incorporated into or otherwise a part of, an eNB, a UE, a network node, or some other type of electronic device. In embodiments, the electronic device circuitry 700 may include radio transmit circuitry 710 and receive circuitry 712 coupled to control circuitry 714. In embodiments, the transmit circuitry 710 and/or receive circuitry 712 may be elements or modules of transceiver circuitry, as shown. The electronic device circuitry 700 may be coupled with one or more antenna elements 716 of one or more antennas. The electronic device circuitry 700 and/or the components of the electronic device circuitry 700 may be configured to perform operations similar to those described elsewhere in this disclosure.

[0046] FIG. 8 is a block diagram illustrating, for one embodiment, example components of a UE device 800. In some embodiments, the UE device 800 may include application circuitry 802, baseband circuitry 804, radio frequency (RF)

circuitry 806, front-end module (FEM) circuitry 808, and one or more antennas 810, coupled together at least as shown in FIG. 8.

[0047] The application circuitry 802 may include one or more application processors. By way of non-limiting example, the application circuitry 802 may include 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 processor(s) may be operably coupled to and/or 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.

[0048] By way of non-limiting example, the baseband circuitry 804 may include one or more single-core or multi-core processors. The baseband circuitry 804 may include one or more baseband processors and/or control logic. The baseband circuitry 804 may be configured to process baseband signals received from a receive signal path of the RF circuitry 806. The baseband circuitry 804 may also be configured to generate baseband signals for a transmit signal path of the RF circuitry 806. The baseband circuitry 804 may interface with the application circuitry 802 for generation and processing of the baseband signals, and for controlling operations of the RF circuitry 806.

[0049] By way of non-limiting example, the baseband circuitry 804 may include at least one of a fifth generation (5G) baseband processor 804A, a fourth generation (4G) baseband processor 804B, a third generation (3G) baseband processor 804C, and other baseband processor(s) 804D for other existing generations and generations in development or to be developed in the future (e.g., sixth generation (6G), etc.). The baseband circuitry 804 (e.g., at least one of the baseband processors 804A–804D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 806. By way of non-limiting example, the radio control functions may include signal modulation/demodulation, encoding/decoding, radio frequency shifting, other functions, and combinations thereof. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 804 may be programmed to perform fast Fourier transform (FFT), precoding, constellation mapping/demapping functions, other functions, and combinations thereof. In some embodiments, encoding/decoding circuitry of the baseband circuitry 804 may be programmed to

perform convolutions, tail-biting convolutions, turbo, Viterbi, Low Density Parity Check (LDPC) encoder/decoder functions, other functions, and combinations thereof. Embodiments of modulation/demodulation and encoder/decoder functions are not limited to these examples, and may include other suitable functions.

[0050] In some embodiments, the baseband circuitry 804 may include elements of a protocol stack. By way of non-limiting example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol include, 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) 804E of the baseband circuitry 804 may be programmed 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 804 may include one or more audio digital signal processor(s) (DSP) 804F. The audio DSP(s) 804F may include elements for compression/decompression and echo cancellation. The audio DSP(s) 804F may also include other suitable processing elements.

[0051] The baseband circuitry 804 may further include memory/storage 804G. The memory/storage 804G may include data and/or instructions for operations performed by the processors of the baseband circuitry 804 stored thereon. In some embodiments, the memory/storage 804G may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 804G may also include any combination of various levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. In some embodiments, the memory/storage 804G may be shared among the various processors or dedicated to particular processors.

[0052] Components of the baseband circuitry 804 may be suitably combined in a single chip or 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 804 and the application circuitry 802 may be implemented together, such as, for example, on a system on a chip (SOC).

[0053] In some embodiments, the baseband circuitry 804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 804 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), or a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0054] The RF circuitry 806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 806 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. The RF circuitry 806 may include a receive signal path, which may include circuitry to down-convert RF signals received from the FEM circuitry 808, and provide baseband signals to the baseband circuitry 804. The RF circuitry 806 may also include a transmit signal path, which may include circuitry to up-convert baseband signals provided by the baseband circuitry 804, and provide RF output signals to the FEM circuitry 808 for transmission.

[0055] In some embodiments, the RF circuitry 806 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 806 may include mixer circuitry 806A, amplifier circuitry 806B, and filter circuitry 806C. The transmit signal path of the RF circuitry 806 may include the filter circuitry 806C and the mixer circuitry 806A. The RF circuitry 806 may further include synthesizer circuitry 806D configured to synthesize a frequency for use by the mixer circuitry 806A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 806A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 808 based on the synthesized frequency provided by the synthesizer circuitry 806D. The amplifier circuitry 806B may be configured to amplify the down-converted signals.

[0056] The filter circuitry 806C may include 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 804 for further processing. In some embodiments, the output baseband signals may include zero-frequency baseband signals, although this is optional, of course. In some embodiments, the mixer circuitry 806A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0057] In some embodiments, the mixer circuitry 806A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 806D to generate RF output signals for the FEM circuitry 808. The baseband signals may be provided by the baseband circuitry 804 and may be filtered by the filter circuitry 806C. The filter circuitry 806C may include an LPF, although the scope of the embodiments is not limited in this respect.

[0058] In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A 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 806A of the receive signal path and the mixer circuitry 806A 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 806A of the receive signal path and the mixer circuitry 806A of the transmit signal path may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 806A of the receive signal path and the mixer circuitry 806A of the transmit signal path may be configured for super-heterodyne operation.

[0059] 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 other embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In such embodiments, the RF circuitry 806 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and the baseband circuitry 804 may include a digital baseband interface to communicate with the RF circuitry 806.

[0060] In some dual-mode embodiments, separate radio integrated circuit (IC) circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

[0061] In some embodiments, the synthesizer circuitry 806D may include one or more of a fractional-N synthesizer and 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, the synthesizer circuitry 806D may include a delta-sigma synthesizer, a frequency multiplier, a synthesizer comprising a

phase-locked loop with a frequency divider, other synthesizers, and combinations thereof.

[0062] The synthesizer circuitry 806D may be configured to synthesize an output frequency for use by the mixer circuitry 806A of the RF circuitry 806 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 806D may be a fractional $N/N+1$ synthesizer.

[0063] In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO). Divider control input may be provided by either the baseband circuitry 804 or the application circuitry 802 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 application circuitry 802.

[0064] The synthesizer circuitry 806D of the RF circuitry 806 may include a divider, a delay-locked loop (DLL), a multiplexer, and a phase accumulator. In some embodiments, the divider may include a dual modulus divider (DMD), and the phase accumulator may include 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 such 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 may provide negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

[0065] In some embodiments, the synthesizer circuitry 806D may be configured to generate a carrier frequency as the output frequency. In some embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency, etc.) and used in conjunction with a 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 806 may include an IQ/polar converter.

[0066] The FEM circuitry 808 may include a receive signal path, which may include circuitry configured to operate on RF signals received from one or more

antennas 810, amplify the received signals, and provide the amplified versions of the received signals to the RF circuitry 806 for further processing. The FEM circuitry 808 may also include a transmit signal path, which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 806 for transmission by at least one of the antennas 810.

[0067] In some embodiments, the FEM circuitry 808 may include a TX/RX switch configured to switch between a transmit mode and a receive mode operation. The FEM circuitry 808 may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry 808 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 806). The transmit signal path of the FEM circuitry 808 may include a power amplifier (PA) configured to amplify input RF signals (e.g., provided by RF circuitry 806), and one or more filters configured to generate RF signals for subsequent transmission (e.g., by one or more of the antennas 810).

[0068] In some embodiments, the UE device 800 may include additional elements such as, for example, memory/storage, a display, a camera, one or more sensors, an input/output (I/O) interface, other elements, and combinations thereof.

[0069] In some embodiments, the UE device 800 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. In the software context, various techniques, or certain aspects or portions thereof, may take the form of program code (i.e., instructions) embodied in tangible media, such as floppy diskettes, CD-ROMs, hard drives, a non-transitory computer readable storage medium, or any other machine-readable storage medium wherein, when the program code is loaded into and executed by a machine, such as a computer, the machine becomes an apparatus for practicing the various techniques. In the case of program code execution on programmable computers, the computing device may include a processor, a storage medium readable by the processor (including volatile and non-volatile memory and/or storage elements), at least one input device, and at least one output device. The volatile and non-volatile memory and/or storage elements may be a RAM, an EPROM, a flash drive, an optical drive, a magnetic hard drive, or another medium for storing electronic data. The eNB (or other base station) and UE (or other mobile station) may also include a transceiver component, a counter component, a

processing component, and/or a clock component or timer component. One or more programs that may implement or utilize the various techniques described herein may use an application programming interface (API), reusable controls, and the like. Such programs may be implemented in a high-level procedural or an object-oriented programming language to communicate with a computer system. However, the program(s) may be implemented in assembly or machine language, if desired. In any case, the language may be a compiled or an interpreted language, and combined with hardware implementations.

[0070] It should be understood that many of the functional units described in this specification may be implemented as one or more components, which is a term used to more particularly emphasize their implementation independence. For example, a component may be implemented as a hardware circuit comprising custom very large scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A component may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, or the like.

[0071] Components may also be implemented in software for execution by various types of processors. An identified component of executable code may, for instance, comprise one or more physical or logical blocks of computer instructions, which may, for instance, be organized as an object, a procedure, or a function. Nevertheless, the executables of an identified component need not be physically located together, but may comprise disparate instructions stored in different locations that, when joined logically together, comprise the component and achieve the stated purpose for the component.

[0072] Indeed, a component of executable code may be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within components, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network. The components may be passive or active, including agents operable to perform desired functions.

[0073] FIG. 9 is a block diagram illustrating components, according to some example embodiments, able to read instructions from a machine-readable or computer-readable medium (e.g., a machine-readable storage medium) and perform any one or more of the methodologies discussed herein. Specifically, FIG. 9 shows a diagrammatic representation of hardware resources 900 including one or more processors (or processor cores) 910, one or more memory/storage devices 920, and one or more communication resources 930, each of which is communicatively coupled via a bus 940.

[0074] The processors 910 (e.g., a central processing unit (CPU), a reduced instruction set computing (RISC) processor, a complex instruction set computing (CISC) processor, a graphics processing unit (GPU), a digital signal processor (DSP) such as a baseband processor, an application specific integrated circuit (ASIC), a radio-frequency integrated circuit (RFIC), another processor, or any suitable combination thereof) may include, for example, a processor 912 and a processor 914. The memory/storage devices 920 may include main memory, disk storage, or any suitable combination thereof.

[0075] The communication resources 930 may include interconnection and/or network interface components or other suitable devices to communicate with one or more peripheral devices 904 and/or one or more databases 906 via a network 908. For example, the communication resources 930 may include wired communication components (e.g., for coupling via a Universal Serial Bus (USB)), cellular communication components, Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components.

[0076] Instructions 950 may comprise software, a program, an application, an applet, an app, or other executable code for causing at least one of the processors 910 to perform any one or more of the methodologies discussed herein. The instructions 950 may reside, completely or partially, within at least one of the processors 910 (e.g., within the processor's cache memory), the memory/storage devices 920, or any suitable combination thereof. Furthermore, any portion of the instructions 950 may be transferred to the hardware resources 900 from any combination of the peripheral devices 904 and/or the databases 906. Accordingly, the memory of the processors 910, the memory/storage devices 920, the peripheral

devices 904, and the databases 906 are examples of computer-readable and machine-readable media.

Examples

[0077] Reference throughout this specification to “an example” means that a particular feature, structure, or characteristic described in connection with the example is included in at least one embodiment. Thus, appearances of the phrase “in an example” in various places throughout this specification are not necessarily all referring to the same embodiment.

[0078] Example 1. An apparatus of a wearable user equipment (wUE) configured to establish, according to a layer one (L1) communication procedure, an Xu-a air interface having multiple component physical channels that facilitate wireless communication between the wUE and a network user equipment (nUE), the apparatus comprising circuitry to: process synchronization and system information associated with the nUE; generate a random access (RA) for transmission in a first physical resource block of a physical RA channel of the multiple component physical channels; and process a random access response (RAR) provided by the nUE in response to the RA in a second physical resource block of a physical RAR channel of the multiple component physical channels, the second physical resource block being at a relative location in the physical RAR channel that is the same as that of the RA in the physical RA channel.

[0079] Example 2. The apparatus of example 1, in which the circuitry is further configured to: process a physical synchronization channel to obtain the synchronization information; and process a physical broadcast channel to obtain the system information, in which the physical synchronization channel and the physical broadcast channel are temporally adjacent and provided by a synchronization source during a synchronization interval having multiple downlink (DL) and uplink (UL) periods.

[0080] Example 3. The apparatus of example 2, in which the synchronization source is the nUE acting as a donor nUE or associated with another nUE that is commonly located with the donor nUE in a single-frequency-network (SFN)-type synchronization cluster.

[0081] Example 4. The apparatus of any of examples 1–3, in which the multiple component physical channels further comprise a physical synchronization channel, a

physical broadcast channel, a dedicated physical control channel, and a physical data channel.

[0082] Example 5. The apparatus of any of examples 1–4, in which the nUE is a donor nUE and the synchronization and system information associated with the donor nUE is delivered by a synchronization source nUE associated with the donor nUE.

[0083] Example 6. The apparatus of any of examples 1–5, in which the circuitry is further configured to randomly select the first physical resource block from a predefined RA resource allocation.

[0084] Example 7. The apparatus of any of examples 1–6, in which the circuitry is further configured to process a physical broadcast channel to obtain the system information including a bitmap defining an RA resource allocation useable by the wUE for selecting a location of the first physical resource block.

[0085] Example 8. A method performed by a wearable user equipment (wUE) according to a layer one (L1) communication procedure of establishing an Xn air interface having multiple component physical channels facilitating wireless communication between the wUE and a network user equipment (nUE), the method comprising: processing synchronization and system information associated with the nUE; generating a random access (RA) for transmission in a first physical resource block of a physical RA channel of the multiple component physical channels; and processing a random access response (RAR) provided in response to the RA in a second physical resource block of a physical RAR channel of the multiple component physical channels, the second physical resource block being at a relative location in the physical RAR channel that is the same as that of the RA in the physical RA channel.

[0086] Example 9. The method of example 8, further comprising: processing a physical synchronization channel to obtain the synchronization information; and processing a physical broadcast channel to obtain the system information, in which the physical synchronization channel and the physical broadcast channel are temporally adjacent and provided by a synchronization source during a synchronization interval having multiple downlink (DL) and uplink (UL) periods.

[0087] Example 10. The method of example 9, in which the synchronization source is the nUE acting as a donor nUE or associated with another nUE that is

commonly located with the donor nUE in a single-frequency-network (SFN)-type synchronization cluster.

[0088] Example 11. The method of any of examples 8–10, in which the multiple component physical channels further comprise a physical synchronization channel, a physical broadcast channel, a dedicated physical control channel, and a physical data channel.

[0089] Example 12. The method of any of examples 8–11, in which the nUE is a donor nUE and the synchronization and system information associated with the donor nUE is delivered by a synchronization source nUE associated with the donor nUE.

[0090] Example 13. The method of any of examples 8–12, further comprising randomly selecting the first physical resource block from a predefined RA resource allocation.

[0091] Example 14. The method of any of examples 8–13, further comprising processing a physical broadcast channel to obtain the system information including a bitmap defining an RA resource allocation useable by the wUE for selecting a location of the first physical resource block.

[0092] Example 15. An apparatus of a wearable user equipment (wUE) configured to obtain physical resources for wireless communications with a network user equipment (nUE) through an Xu-a air interface, the apparatus comprising circuitry to: randomly select, from a random access (RA) resource partition of a physical RA channel of the Xu-a air interface, a first physical resource block by which to provide an RA in the physical RA channel; generate the RA in the first physical resource block; and process a random access response (RAR) from the nUE in response to the RA to determine the physical resources for the wireless communications, the RAR being provided in a second physical resource block of a physical RAR channel of the Xu-a air interface, the second physical source block located at an RAR resource partition of the physical RAR channel that matches that of the first physical source block.

[0093] Example 16. The apparatus of example 15, in which the circuitry is further configured to obtain the RA resource partition through broadcast information provided by the nUE in a physical broadcast channel.

[0094] Example 17. The apparatus of example 15 or 16, in which the circuitry is further configured to obtain the RA resource partition from a bitmap defining an RA resource allocation.

[0095] Example 18. The apparatus of any of examples 15–17, in which the circuitry is further configured to randomly select multiple physical resource blocks by which to provide redundancy for the RA in the physical RA channel.

[0096] Example 19. The apparatus of example 18, in which the circuitry is further configured to process a broadcast channel to determine a number of the multiple physical resource blocks to randomly select.

[0097] Example 20. The apparatus of any of examples 15–19, in which the circuitry is further configured to process a downlink (DL) subframe indicated by the RAR to determine from a cross-subframe DL dedicated physical control channel the physical resources for wireless communications during a subsequent subframe.

[0098] Example 21. A method performed by a wearable user equipment (wUE) of obtaining physical resources for wireless communications with a network user equipment (nUE) through an Xu-a air interface, the method comprising: randomly selecting, from a random access (RA) resource partition of a physical RA channel of the Xu-a air interface, a first physical resource block by which to provide an RA in the physical RA channel; generating the RA in the first physical resource block; and processing a random access response (RAR) from the nUE in response to the RA to determine the physical resources for the wireless communications, the RAR being provided in a second physical resource block of a physical RAR channel of the Xu-a air interface, the second physical source block located at an RAR resource partition of the physical RAR channel that matches that of the first physical source block.

[0099] Example 22. The method of example 21, further comprising obtaining the RA resource partition through broadcast information provided by the nUE in a physical broadcast channel.

[0100] Example 23. The method of example 21 or 22, further comprising obtaining the RA resource partition from a bitmap of an RA resource allocation.

[0101] Example 24. The method of any of examples 21–23, further comprising randomly selecting multiple physical resource blocks by which to provide redundancy for the RA in the physical RA channel.

[0102] Example 25. The method of example 24, further comprising processing a broadcast channel to determine a number of the multiple physical resource blocks to randomly select.

[0103] Example 26. The method any of examples 21–25, further comprising processing a downlink (DL) subframe indicated by the RAR to determine from a cross-subframe DL dedicated physical control channel the physical resources for wireless communications during a subsequent subframe.

[0104] Example 27. An apparatus of a network user equipment (nUE) configured to assist a wearable user equipment (wUE) in accessing, through an Xu-a interface, control- and user-plane functions of a long-term evolution (LTE) wireless wide area network (WWAN) comprising the nUE and a base station, the apparatus comprising circuitry to: provide, in a physical synchronization channel, a synchronization signal for transmission during a synchronization interval; provide, in a physical broadcast channel following the physical synchronization channel, a resource allocation of random access (RA) opportunities for transmission during the synchronization interval; process an RA obtained from the wUE in a physical RA channel following the physical broadcast channel and during an RA and paging interval partly overlapping the synchronization interval; and generate, for a physical RAR channel following the physical RA channel, a random access response (RAR) for transmission during the RA and paging interval, the RAR including a dedicated physical control channel indicating resources available in a subsequent subframe by which to assist the wUE in wireless communications with the WWAN through the Xu-a interface.

[0105] Example 28. The apparatus of example 27, in which the circuitry is further configured to indicate the nUE become a synchronization source for retransmission of the synchronization signal in response to detecting the synchronization signal transmitted from another nUE is at a power level below a threshold.

[0106] Example 29. The apparatus of example 27 or 28, in which the circuitry is further configured to indicate the nUE become a synchronization source for retransmission of the synchronization signal in response to available power of the nUE being above a threshold.

[0107] Example 30. The apparatus of any of examples 27–29, in which the circuitry is further configured to provide a resource allocation of RA opportunities by generating a bitmap defining the resource allocation.

[0108] Example 31. The apparatus of any of examples 27–30, in which the circuitry is further configured to provide an intra-subframe downlink (DL) dedicated physical control channel for modulation coding scheme and intra-personal area network (PAN) resource allocation.

[0109] Example 32. The apparatus of any of examples 27–31, in which the circuitry is further configured to provide a cross-subframe downlink (DL) dedicated physical control channel for resource assignment of a data subframe.

[0110] Example 33. The apparatus of any of examples 27–32, in which the circuitry is further configured to generate a self-contained subframe including data and feedback channels.

[0111] Example 34. A method performed by a network user equipment (nUE) of assisting a wearable user equipment (wUE) in accessing, through an Xu-a interface, control- and user-plane functions of a long-term evolution (LTE) wireless wide area network (WWAN) comprising the nUE and a base station, the method comprising: providing, in a physical synchronization channel, a synchronization signal for transmission during a synchronization interval; providing, in a physical broadcast channel following the physical synchronization channel, a resource allocation of random access (RA) opportunities for transmission during the synchronization interval; processing an RA obtained from the wUE in a physical RA channel following the physical broadcast channel and during an RA and paging interval partly overlapping the synchronization interval; and generating, for a physical RAR channel following the physical RA channel, a random access response (RAR) for transmission during the RA and paging interval, the RAR including a dedicated physical control channel indicating resources available in a subsequent subframe by which to assist the wUE in wireless communications with the WWAN through the Xu-a interface.

[0112] Example 35. The method of example 34, further comprising becoming a synchronization source by retransmitting the synchronization signal in response to detecting the synchronization signal transmitted from another nUE and at a power level below a threshold.

[0113] Example 36. The method of example 34 or 35, further comprising becoming a synchronization source by retransmitting the synchronization signal in response to a residual power of the nUE being above a threshold.

[0114] Example 37. The method of any of examples 34–36, further comprising providing a resource allocation of RA opportunities by generating a bitmap defining the resource allocation.

[0115] Example 38. The method of any of examples 34–37, further comprising providing an intra-subframe downlink (DL) dedicated physical control channel for modulation coding scheme and intra-personal area network (PAN) resource allocation.

[0116] Example 39. The method of any of examples 34–38, further comprising providing a cross-subframe downlink (DL) dedicated physical control channel for resource assignment of a data subframe.

[0117] Example 40. The method of any of examples 34–39, further comprising generating a self-contained subframe including data and feedback channels.

[0118] Example 41. An apparatus comprising means to perform one or more elements of a method described in or related to any of examples 8–14, 21–26, or 34–40, and/or any other method or process described herein.

[0119] Example 42. One or more non-transitory (or transitory) computer-readable media comprising instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of a method described in or related to any of examples 8–14, 21–26, or 34–40, and/or any other method or process described herein.

[0120] Example 43. An apparatus comprising control logic, transmit logic, and/or receive logic to perform one or more elements of a method described in or related to any of examples 8–14, 21–26, or 34–40, and/or any other method or process described herein.

[0121] Example 44. A method of communicating in a wireless network as shown and described herein.

[0122] Example 45. A system for providing wireless communication as shown and described herein.

[0123] Example 46. A device for providing wireless communication as shown and described herein.

[0124] Example 47 may contain a method of L1 procedure for intra-PAN (personal area network) communication as defined in FIG. 2.

[0125] Example 48 may contain a method of providing physical channels for intra-PAN communication as defined in FIG. 3.

[0126] Example 49 may contain a method for the nUEs (network user equipment) and wUEs (wearable UE) to form synchronization clusters.

[0127] Example 50 may contain the wUE-initiated resource acquisition.

[0128] Example 51 may contain the wUE-dedicated control and data.

[0129] Example 52 may contain the self-contained subframe structure.

[0130] Skilled persons will understand that many changes may be made to the details of the above-described embodiments without departing from the underlying principles of the invention. For example, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. Lists, however, should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on its presentation in a common group without indications to the contrary. In addition, various embodiments and examples may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of embodiments. The scope of the present invention should, therefore, be determined only by the following claims.

CLAIMS

1. An apparatus of a wearable user equipment (wUE), the apparatus comprising circuitry to:
 - process synchronization and system information associated with the nUE;
 - generate a random access (RA) attempt to establish, according to a layer one (L1) communication procedure, an Xu-a air interface having multiple component physical channels that facilitate wireless communication between the wUE and a network user equipment (nUE), the RA for transmission in a first physical resource block of a physical RA channel of the multiple component physical channels; and
 - process a random access response (RAR) provided by the nUE in response to the RA in a second physical resource block of a physical RAR channel of the multiple component physical channels, the second physical resource block being at a relative location in the physical RAR channel that is the same as that of the RA in the physical RA channel.
2. The apparatus of claim 1, in which the circuitry is further configured to:
 - process a physical synchronization channel to obtain the synchronization information; and
 - process a physical broadcast channel to obtain the system information, in which the physical synchronization channel and the physical broadcast channel are temporally adjacent and provided by a synchronization source during a synchronization interval having multiple downlink (DL) and uplink (UL) periods.
3. The apparatus of claim 2, in which the synchronization source is the nUE acting as a donor nUE or associated with another nUE that is commonly located with the donor nUE in a single-frequency-network (SFN)-type synchronization cluster.
4. The apparatus of any of claims 1–3, in which the multiple component physical channels further comprise a physical synchronization channel, a physical broadcast channel, a dedicated physical control channel, and a physical data channel.
5. The apparatus of any of claims 1–3, in which the nUE is a donor nUE and the synchronization and system information associated with the donor nUE is delivered by a synchronization source nUE associated with the donor nUE.
6. The apparatus of any of claims 1–3, in which the circuitry is further configured to randomly select the first physical resource block from a predefined RA resource allocation.

7. The apparatus of any of claims 1–3, in which the circuitry is further configured to process a physical broadcast channel to obtain the system information including a bitmap defining an RA resource allocation useable by the wUE for selecting a location of the first physical resource block.

8. An apparatus of a wearable user equipment (wUE), the apparatus comprising circuitry to:

randomly select, from a random access (RA) resource partition of a physical RA channel of an Xu-a air interface, a first physical resource block by which to provide an RA in the physical RA channel;

generate the RA in the first physical resource block to obtain physical resources for wireless communications with a network user equipment (nUE) through the Xu-a air interface; and

process a random access response (RAR) from the nUE in response to the RA to determine the physical resources for the wireless communications, the RAR being provided in a second physical resource block of a physical RAR channel of the Xu-a air interface, the second physical source block located at an RAR resource partition of the physical RAR channel that matches that of the first physical source block.

9. The apparatus of claim 8, in which the circuitry is further configured to obtain the RA resource partition through broadcast information provided by the nUE in a physical broadcast channel.

10. The apparatus of claim 8, in which the circuitry is further configured to obtain the RA resource partition from a bitmap defining an RA resource allocation.

11. The apparatus of claim 8, in which the circuitry is further configured to randomly select multiple physical resource blocks by which to provide redundancy for the RA in the physical RA channel.

12. The apparatus of claim 11, in which the circuitry is further configured to process a broadcast channel to determine a number of the multiple physical resource blocks to randomly select.

13. The apparatus of any of claims 8–12, in which the circuitry is further configured to process a downlink (DL) subframe indicated by the RAR to determine from a cross-subframe DL dedicated physical control channel the physical resources for wireless communications during a subsequent subframe.

14. An apparatus of a network user equipment (nUE), the apparatus comprising circuitry to:

provide, in a physical synchronization channel, a synchronization signal for transmission during a synchronization interval;

provide, in a physical broadcast channel following the physical synchronization channel, a resource allocation of random access (RA) opportunities for transmission during the synchronization interval;

process an RA obtained from a wearable user equipment (wUE) in a physical RA channel following the physical broadcast channel and during an RA and paging interval partly overlapping the synchronization interval; and

generate, for a physical RAR channel following the physical RA channel, a random access response (RAR) for transmission during the RA and paging interval, the RAR including a dedicated physical control channel indicating resources available in a subsequent subframe by which to assist the wUE in accessing, through an X_u-a interface, control- and user-plane functions of a long-term evolution (LTE) wireless wide area network (WWAN) comprising the nUE and a base station.

15. The apparatus of claim 14, in which the circuitry is further configured to indicate the nUE become a synchronization source for retransmission of the synchronization signal in response to detecting the synchronization signal transmitted from another nUE is at a power level below a threshold.

16. The apparatus of claim 14, in which the circuitry is further configured to indicate the nUE become a synchronization source for retransmission of the synchronization signal in response to available power of the nUE being above a threshold.

17. The apparatus of any of claims 14–16, in which the circuitry is further configured to provide a resource allocation of RA opportunities by generating a bitmap defining the resource allocation.

18. The apparatus of any of claims 14–16, in which the circuitry is further configured to provide an intra-subframe downlink (DL) dedicated physical control channel for modulation coding scheme and intra-personal area network (PAN) resource allocation.

19. The apparatus of any of claims 14–16, in which the circuitry is further configured to provide a cross-subframe downlink (DL) dedicated physical control channel for resource assignment of a data subframe.

20. The apparatus of any of claims 14–16, in which the circuitry is further configured to generate a self-contained subframe including data and feedback channels.

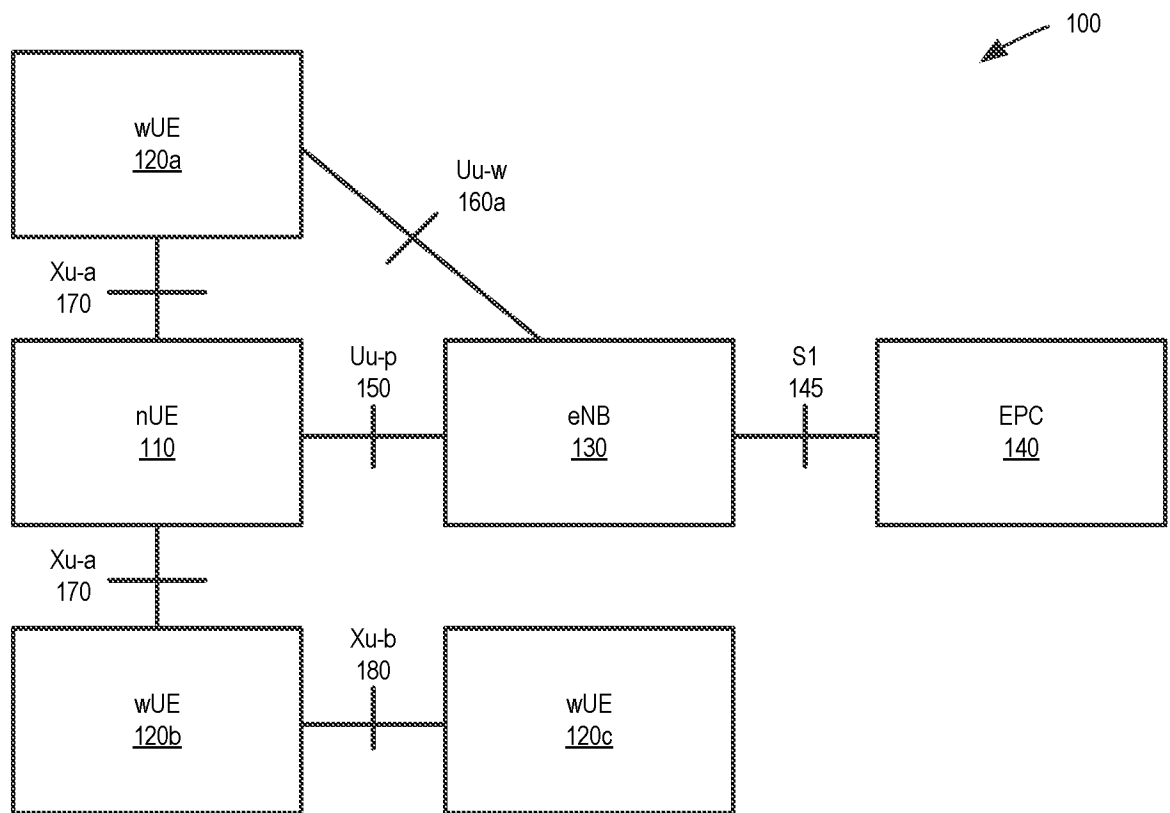


FIG. 1

200

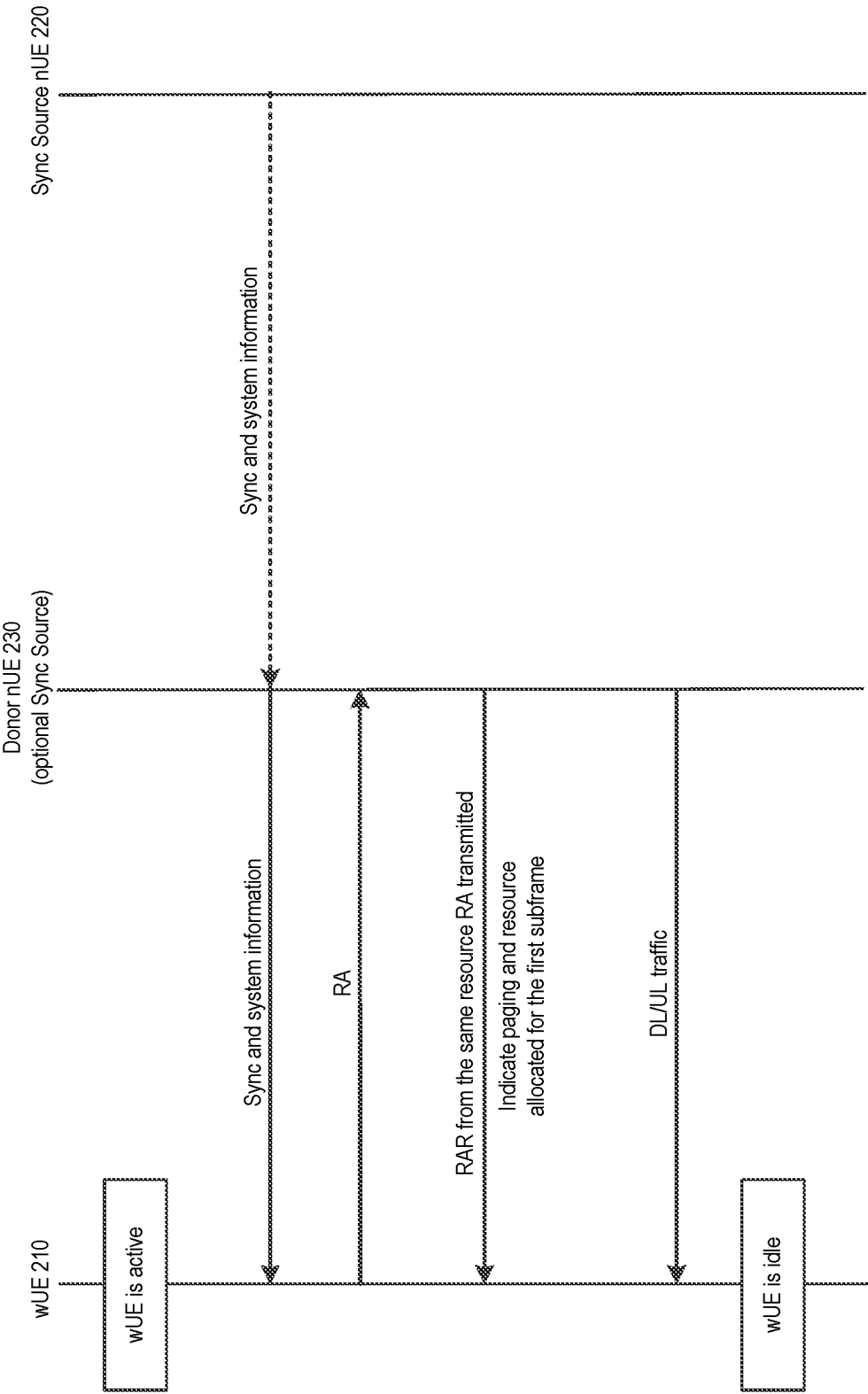


FIG. 2

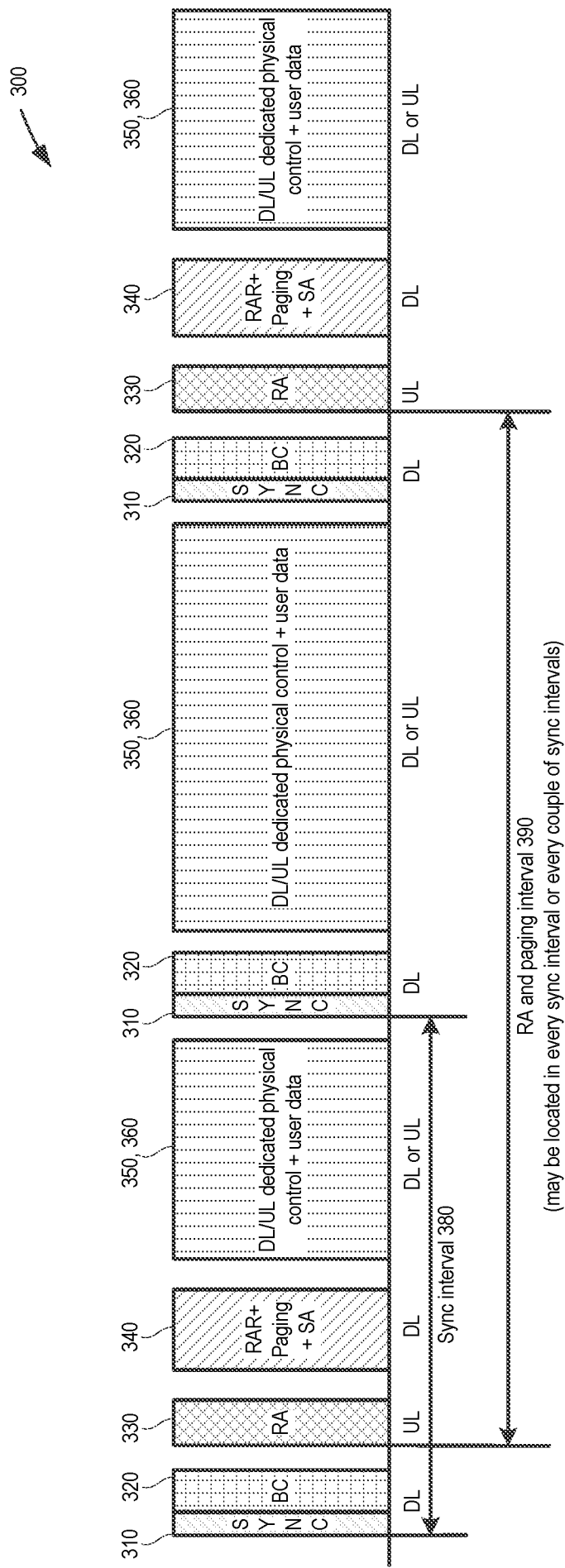


FIG. 3

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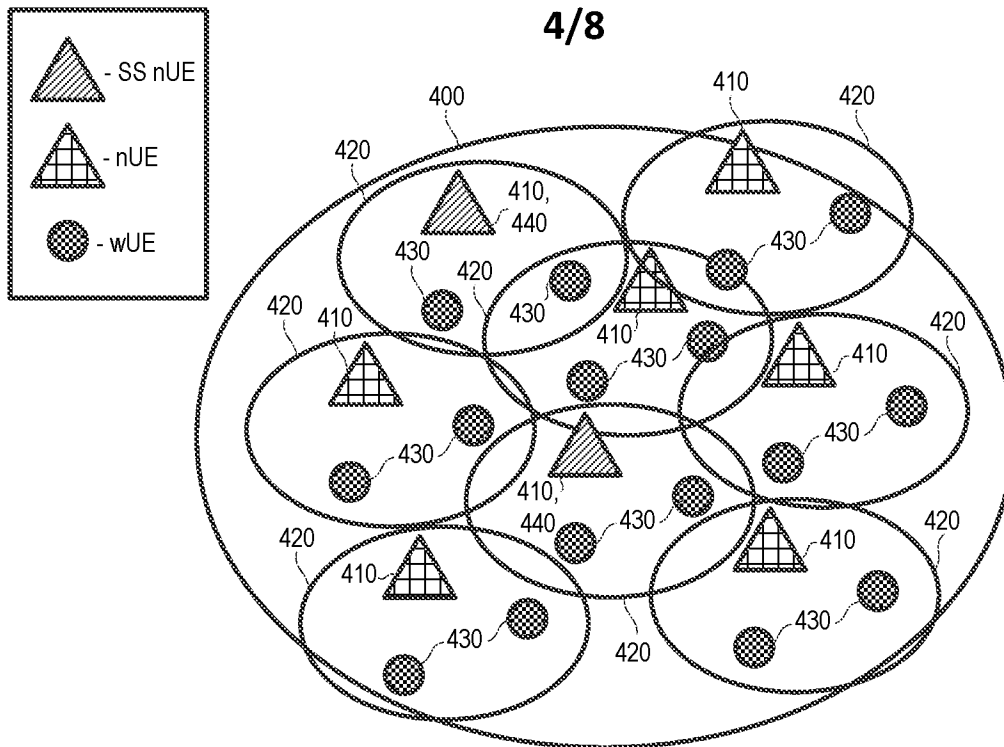


FIG. 4

500

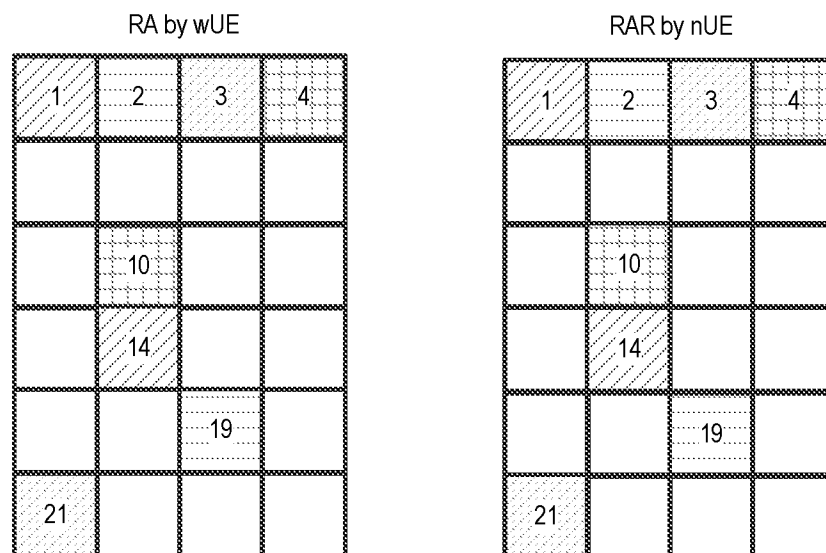


FIG. 5

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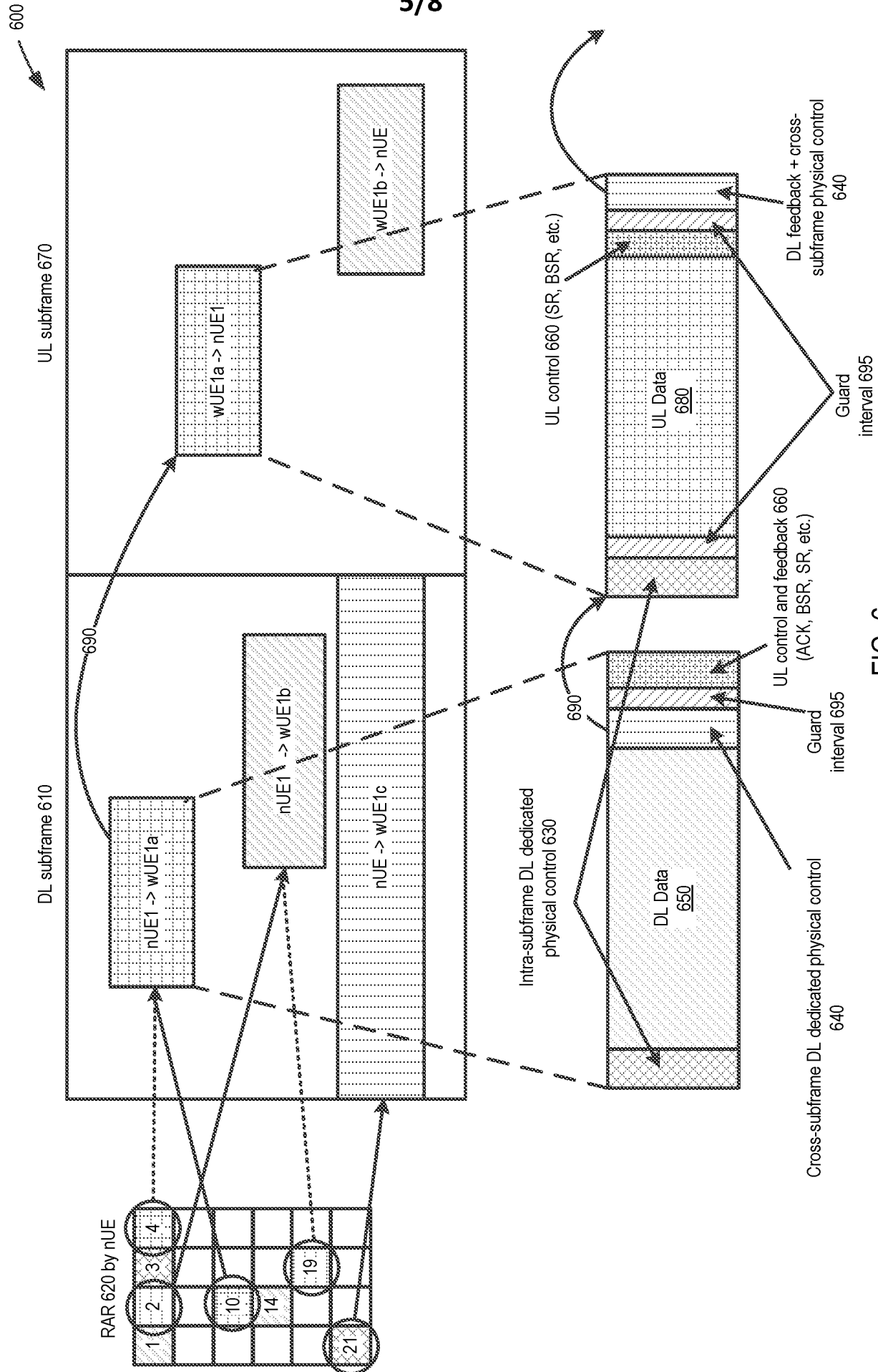


FIG. 6

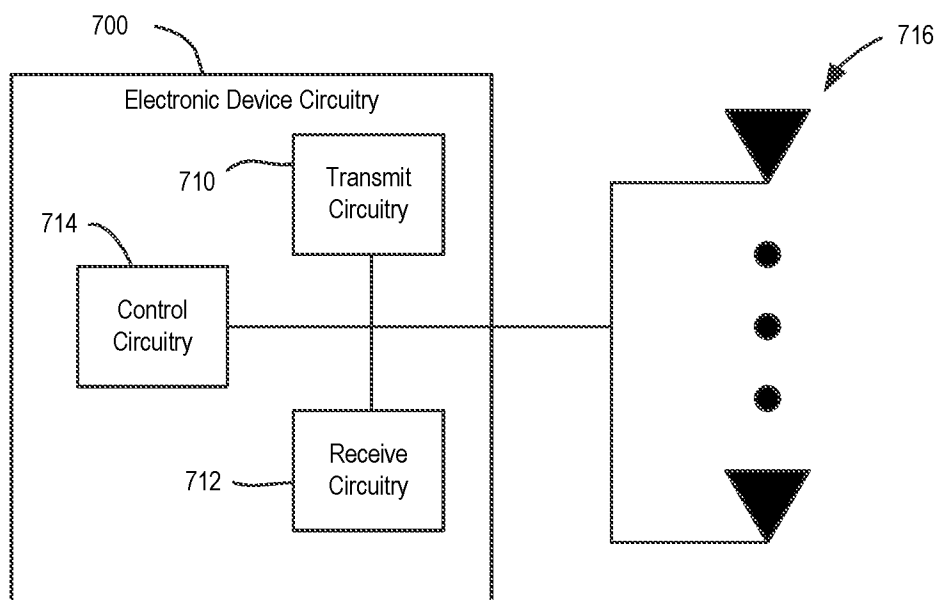


FIG. 7

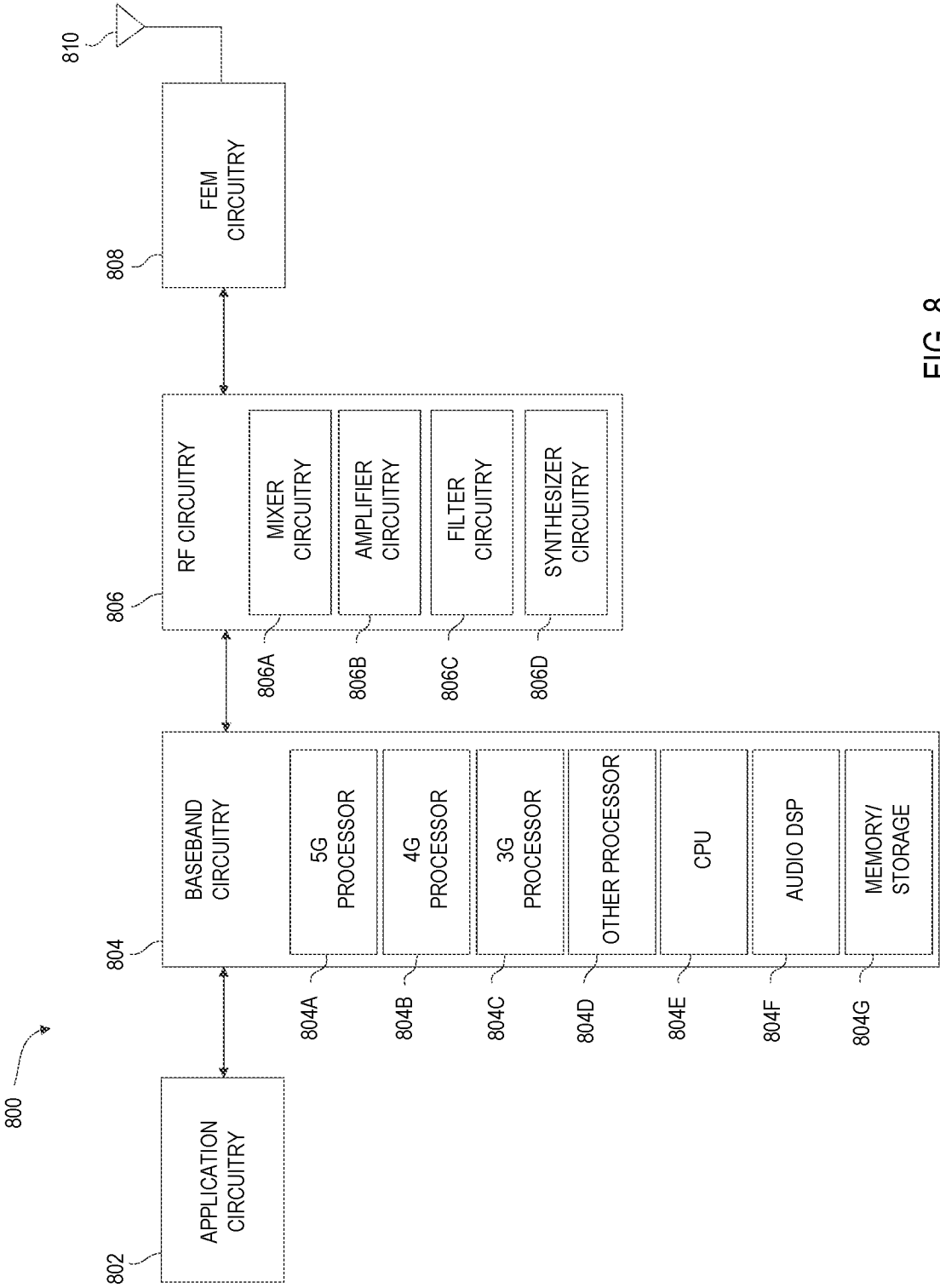


FIG. 8

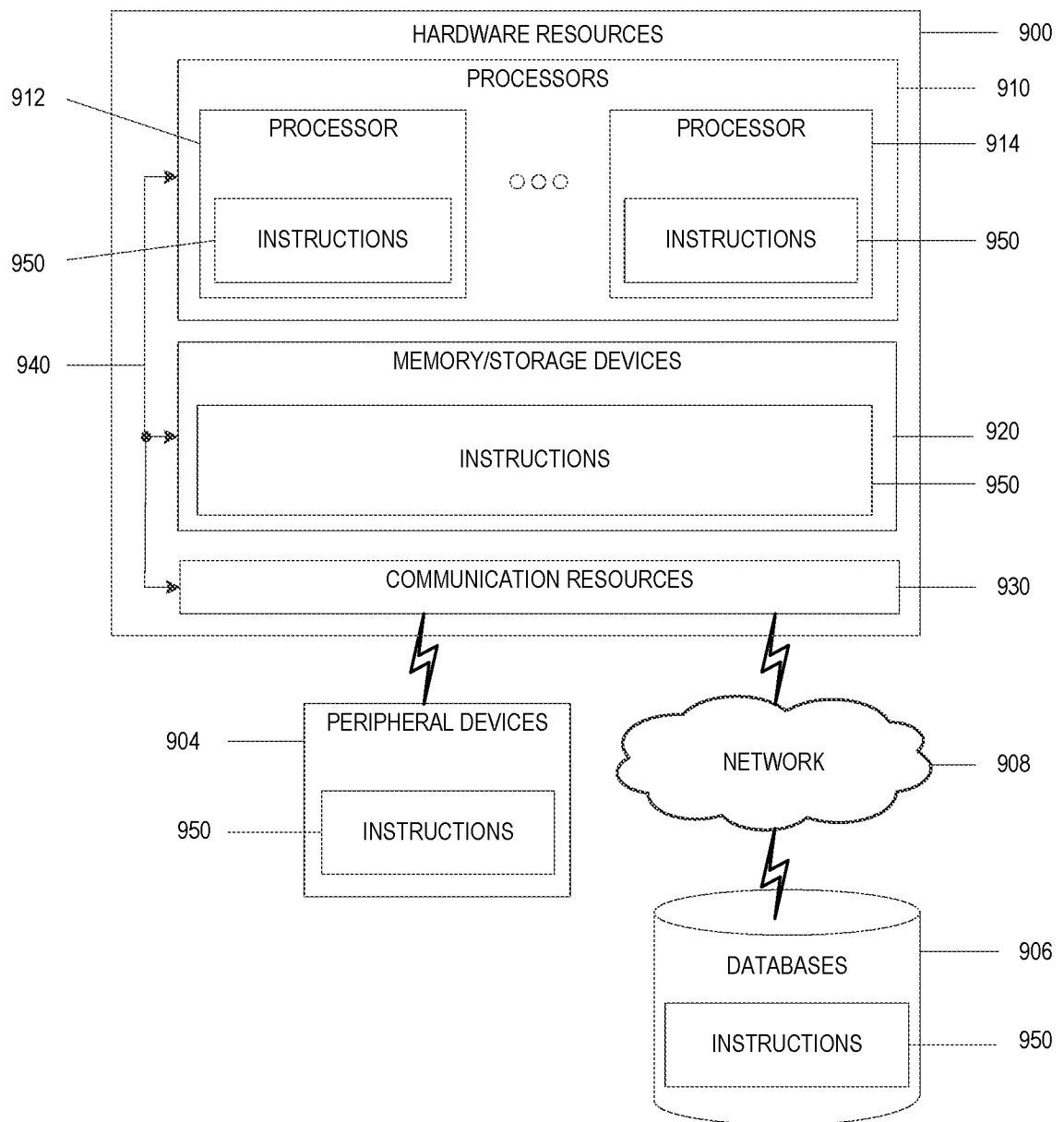


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/040149

A. CLASSIFICATION OF SUBJECT MATTER INV. H04W74/00 ADD. H04W74/08 H04W84/18 H04W88/04 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 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) EP0-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	NOKIA NETWORKS: "RAR Transmission for MTC", 3GPP DRAFT; R1-151312, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Belgrade, Serbia; 20150420 - 20150424 19 April 2015 (2015-04-19), XP050934191, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-04-19] proposal 1 Observation 1 ----- -/--	8-20
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 13 September 2016		Date of mailing of the international search report 22/09/2016
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Domingos, Luis

INTERNATIONAL SEARCH REPORT

International application No

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INTERNATIONAL SEARCH REPORT

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