



(51) International Patent Classification:

H04W 4/80 (2018.01) *H04W 52/38* (2009.01)
H04W 52/50 (2009.01)

(21) International Application Number:

PCT/US2024/041543

(22) International Filing Date:

08 August 2024 (08.08.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/531,514 08 August 2023 (08.08.2023) US

(71) Applicant: **INTERDIGITAL PATENT HOLDINGS, INC.** [US/US]; 200 Bellevue Parkway, Suite 300, Wilmington, Delaware 19809 (US).

(72) Inventors: **BALA, Erdem**; 425 Broadhollow Road, Suite 203, Melville, New York 11747 (US). **MARINIER, Paul**; 1000 Sherbrooke Street, Montreal, Québec H3A 3G4 (CA). **MOSTAFA, Ahmed**; 503-105 Champagne Avenue, Ottawa, Ontario K1S5E5 (CA). **LEE, Moon IL**; 425 Broadhollow Road, Suite 203, Melville, New York 11747 (US). **STERN-BERKOWITZ, Janet**; 111 West 33rd Street, Suite 1420, New York, New York 10120 (US). **HONG, Jongwoo**; 111 West 33rd Street, Suite 1420, New York, New York 10120 (US). **FREDA, Martino**; 1000 Sherbrooke Street, Montreal, Québec H3A 3G4 (CA).

(74) Agent: **SCHMID, Joshua D.**; Volpe Koenig, 30 S. 17th Street, 18th Floor, Philadelphia, Pennsylvania 19103 (US).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM,

(54) Title: METHODS FOR BACKSCATTER POWER BOOSTING

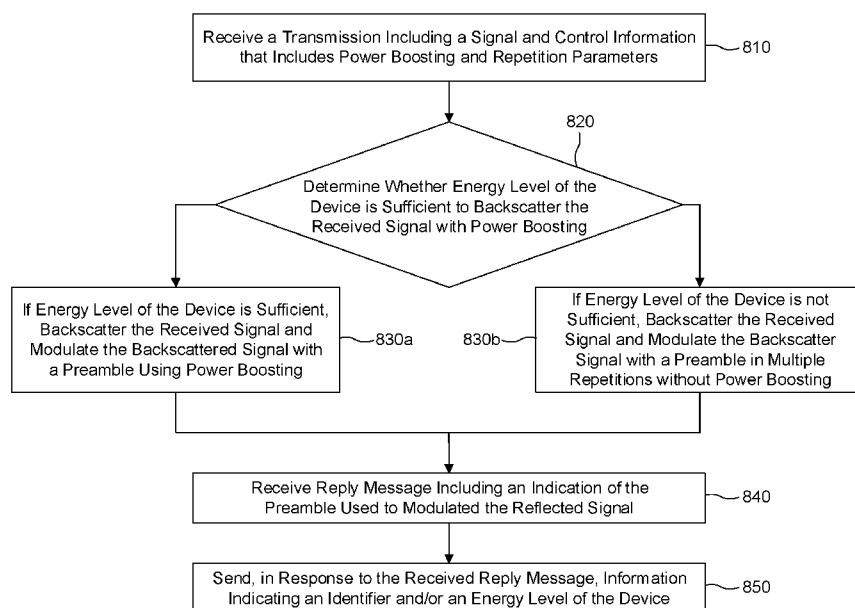


FIG. 8

(57) Abstract: Methods for backscattering radio frequency (RF) signals are provided herein. A method includes receiving a transmission including a signal and control information that includes power boosting and repetition parameters and determining whether an energy level of the device is sufficient to backscatter the signal with power boosting. If the energy level of the device is sufficient to backscatter the received signal with power boosting, the received signal is backscattered and modulated with a preamble using power boosting. If the energy level of the device is not sufficient to backscatter the received signal with power boosting, the received signal is backscattered and modulated with a preamble in multiple repetitions without power boosting. The method includes receiving a reply message including an indication of the preamble used to modulate the backscattered signal and sending, in response to the received reply message, information indicating an identifier or an energy level of the device.

DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

METHODS FOR BACKSCATTER POWER BOOSTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/531,514, filed August 8, 2023, the contents of which are incorporated herein by reference.

BACKGROUND

[0002] The Third Generation Partnership Project (3GPP) has recently started studying ambient Internet of Things (IoT). A goal of the study may be to investigate the feasibility of a new IoT technology to open new markets within 3GPP systems, whose number of connections and/or device density can be orders of magnitude higher than existing 3GPP IoT technologies, and which can provide complexity and power consumption orders-of-magnitude lower than existing 3GPP LPWA technologies such as Narrowband (NB)-IoT and Long-Term Evolution Machine Type Communication (LTE-MTC). In addition, the 3GPP has also initiated a study item in which various use cases for ambient power enabled IoT are being defined.

[0003] Some IoT use cases may involve a backscatter device reflecting an incoming radio frequency (RF) signal without needing to generate its own RF signal. The backscatter device may also modulate an incoming RF signal $S_{in}(t)$ to transmit its own data on the reflected signal. This may be achieved by using the impedance mismatch concept. An antenna impedance Z_A may be connected to a load impedance Z_L at the device. The reflection coefficient then can be defined as $\Gamma = (Z_L - Z_A) / (Z_L + Z_A)$. In general, the reflected signal may be expressed as $S_{out}(t) = \Gamma \times S_{in}(t)$. So, by changing the reflection coefficient (by adjusting the load impedance) over time, the amplitude, frequency, etc. of the reflected signal may be changed. For example, Amplitude Shift Keying modulation may be achieved by using $\Gamma=0$ (non-reflecting state/OFF signal) or $\Gamma = 1$ (reflecting state/ON signal). Radio Frequency Identification (RFID) standards may be based on backscatter communications wherein RFID tags switch the reflection coefficient between two states based on the data being sent. ASK and PSK may supported by the RFID tags.

SUMMARY

[0004] A system of one or more computers can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One or more computer programs can be configured to perform particular operations or actions by virtue of including instructions that, when executed by data processing apparatus, cause the apparatus to perform the actions. One general aspect includes a processor and the transceiver configured to receive a transmission including a signal and control information that includes power boosting and repetition parameters. The processor is configured to determine whether an energy level of the device is sufficient to backscatter the signal with power boosting. If the energy level of the device is sufficient to backscatter the received signal with power boosting, the processor and the transceiver

are configured to backscatter the received signal and modulate the backscattered signal with a preamble using power boosting. If the energy level of the device is not sufficient to backscatter the received signal with power boosting, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble in multiple repetitions without power boosting. The processor and the transceiver are configured to receive a reply message including an indication of the preamble used to modulate the backscattered signal. The processor and the transceiver are configured to send, in response to the received reply message, information indicating an identifier and/or an energy level of the device. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0005] Implementations may include one or more of the following features. The power boosting and repetition parameters include an indication whether power boosting is enabled or disabled, an indication of at least a first power level, and an indication of a repetition factor. If the energy level of the device is sufficient to backscatter the received signal with power boosting, the received signal is backscattered and modulated with a preamble using power boosting. If the energy level of the device is not sufficient to backscatter the received signal with power boosting, the received signal is backscattered and modulated with a preamble in multiple repetitions at the first power level. The indication of the preamble used to modulate the backscattered signal is an indication of a cyclic shift of the preamble. The control information includes an indication of at least a first preamble length and a second preamble length. The processor and the transceiver are configured to use the second preamble length to modulate the backscattered signal based on whether the reply message includes an indication of the preamble used to modulate the backscattered signal. The processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a backoff period. The processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a delay. The delay is selected randomly from a set of a configured delay values. The device is an internet of things (IoT) device. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings, wherein like reference numerals in the figures indicate like elements, and wherein:

[0007] FIG. 1A is a system diagram illustrating an example communications system in which one or more disclosed embodiments may be implemented;

[0008] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0009] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0010] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A according to an embodiment;

[0011] FIG. 2 is a diagram illustrating an example of two preamble sequences of different lengths;

[0012] FIG. 3 is an example of a timing diagram illustrating a signal that may be used to modulate a preamble in accordance with one or more methods described herein;

[0013] FIG. 4 is a diagram illustrating an example of a method for backscattering of preamble transmissions;

[0014] FIG. 5 is a diagram illustrating an example of a method for contention resolution; and

[0015] FIG. 6 is a flow diagram further describing an example of a procedure, which may be performed by an IoT device, for backscatter power boosting;

[0016] FIG. 7 is a flow diagram further describing an example of a procedure, which may be performed by a device such as an interrogator, for enabling the backscattering signals and for receiving said backscattered signals; and

[0017] FIG. 8 is flow diagram describing another example of a procedure, which may be performed by a device, for backscattering signals with power boosting.

DETAILED DESCRIPTION

[0018] FIG. 1A is a diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), zero-tail unique-word discrete Fourier transform Spread OFDM (ZT-UW-DFT-S-OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0019] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104, a core network (CN) 106, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which

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

[0020] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d to facilitate access to one or more communication networks, such as the CN 106, the Internet 110, and/or the other networks 112. By way of example, the base stations 114a, 114b may be a base transceiver station (BTS), a NodeB, an eNode B (eNB), a Home Node B, a Home eNode B, a next generation NodeB, such as a gNode B (gNB), a new radio (NR) NodeB, a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0021] The base station 114a may be part of the RAN 104, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, and the like. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum, unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in one embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0022] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0023] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA,

and the like. For example, the base station 114a in the RAN 104 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink (DL) Packet Access (HSDPA) and/or High-Speed Uplink (UL) Packet Access (HSUPA).

[0024] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0025] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using NR.

[0026] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0027] In other embodiments, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (WiFi)), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0028] The base station 114b in FIG. 1A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In one embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR etc.) to establish a picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106.

[0029] The RAN 104 may be in communication with the CN 106, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or

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

[0030] The CN 106 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or the other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet 110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104 or a different RAT.

[0031] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0032] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0033] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the

transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together in an electronic package or chip.

[0034] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in one embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0035] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. More specifically, the WTRU 102 may employ MIMO technology. Thus, in one embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0036] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0037] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0038] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0039] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0040] The processor 118 may further be coupled to other peripherals 138, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a Virtual Reality and/or Augmented Reality (VR/AR) device, an activity tracker, and the like. The peripherals 138 may include one or more sensors. The sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor, an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, a humidity sensor and the like.

[0041] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the UL (e.g., for transmission) and DL (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the UL (e.g., for transmission) or the DL (e.g., for reception)).

[0042] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0043] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a.

[0044] Each of the eNode-Bs 160a, 160b, 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0045] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0046] The MME 162 may be connected to each of the eNode-Bs 162a, 162b, 162c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0047] The SGW 164 may be connected to each of the eNode Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0048] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0049] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0050] Although the WTRU is described in FIGS. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0051] In representative embodiments, the other network 112 may be a WLAN.

[0052] A WLAN in Infrastructure Basic Service Set (BSS) mode may have an Access Point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have access or an interface to a

Distribution System (DS) or another type of wired/wireless network that carries traffic in to and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an "ad-hoc" mode of communication.

[0053] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) may be implemented, for example in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0054] High Throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0055] Very High Throughput (VHT) STAs may support 20MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous 20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse Fast Fourier Transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above described operation for the 80+80 configuration may be reversed, and the combined data may be sent to the Medium Access Control (MAC).

[0056] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz, and 20 MHz bandwidths in the TV White Space (TVWS)

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

[0057] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or Network Allocation Vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode) transmitting to the AP, all available frequency bands may be considered busy even though a majority of the available frequency bands remains idle.

[0058] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0059] FIG. 1D is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0060] The RAN 104 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 104 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In one embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the gNBs 180a, 180b, 180c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0061] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, the OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., containing a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0062] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0063] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, DC, interworking between NR and E-UTRA, routing of user plane data towards User Plane Function (UPF) 184a, 184b, routing of control plane information towards Access and Mobility Management Function (AMF) 182a, 182b and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0064] The CN 106 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one Session Management Function (SMF) 183a, 183b, and possibly a Data Network (DN) 185a, 185b. While the foregoing elements are depicted as part of the CN 106, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0065] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of non-access stratum (NAS) signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b in order to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c.

For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and the like. The AMF 182a, 182b may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as WiFi.

[0066] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 106 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 106 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy enforcement and QoS, providing DL data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0067] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 104 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184a, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering DL packets, providing mobility anchoring, and the like.

[0068] The CN 106 may facilitate communications with other networks. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In one embodiment, the WTRUs 102a, 102b, 102c may be connected to a local DN 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0069] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to one or more of: WTRU 102a-d, Base Station 114a-b, eNode-B 160a-c, MME 162, SGW 164, PGW 166, gNB 180a-c, AMF 182a-b, UPF 184a-b, SMF 183a-b, DN 185a-b, and/or any other device(s) described herein, may be performed by one or more emulation devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0070] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network.

The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or performing testing using over-the-air wireless communications.

[0071] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0072] A problem addressed by the embodiments presented herein may be understood as follows. Depending on the use case, the number of devices in an IoT deployment may be significant. For example, thousands of such devices may be deployed in a warehouse to track assets. Efficient medium access mechanisms are needed to reduce collisions and increase system efficiency. In addition, coverage enhancement techniques may be required since some of these devices may be operating in limited coverage areas.

[0073] Common terminology, common principles and observations, components, and common benefits of embodiments presented herein are described in the following paragraphs. In the following, a first device may be referred to as the “interrogator” and may be a base station (e.g., a micro or a pico base station), a relay, a UE, a WTRU, or another device that communicates with a second device. A second device may be referred to as an “IoT device” or simply a “device” or “another device”.

[0074] The term “backscattering,” as used herein may refer to a transmission technique that may be used to transmit signals wirelessly. In some methods, the device may transmit a signal by applying backscattering to an incoming signal. In some examples, backscattering implies the reception of the incoming signal, which may (or may not) involve decoding the incoming signal to derive information or data. Backscattering may be achieved by reflecting an incoming signal. For example, unlike devices performing conventional active transmissions, in which the transmitting devices generate their own RF signals, backscattering devices may modulate incoming RF waves from an external source (like a reader) and reflect them back with encoded information. The backscattered signal may be modulated by the device. The device may be capable of harvesting energy (e.g., from RF signals) and storing the energy in a storage unit (e.g., a capacitor). Backscattering may be useful in systems where energy efficiency is paramount, such as in passive RFID systems and certain wireless sensor networks. This process may reduce power requirements, as the device may not need to produce its own RF signals, relying instead on the energy from the incoming signals for both power and communication.

[0075] The operation of backscattering devices may involve changing the impedance of an antenna to encode data onto the reflected RF signal. This modulation may be achieved using semiconductor switches that alternate between different impedance states, effectively modulating the amplitude or phase of the backscattered signal according to a modulation scheme (e.g., ASK or PSK). By manipulating these parameters, backscattering systems may efficiently transmit data over short to moderate distances, making them ideal for inventory tracking, asset management, and IoT applications.

[0076] A device that is capable of backscattering a signal may be, for example, a “passive radio device,” a “semi-passive radio device,” or an “active radio device”. A passive radio device may refer to any radio device that includes an antenna but lacks active elements, such as an antenna amplifier, or does not amplify a baseband signal for data transmission via backscattering. A passive radio device may contain a baseband circuit that operates using energy induced by radio waves (making it strictly passive) or through local energy harvesting (making it semi-passive). For instance, a passive radio device may not be designed to generate a radio signal, which involves converting electrical energy into an electromagnetic wave. As a result, in some examples, a passive device may not include components such as an amplifier, an up-converter, a radio frequency chain, or a portion of a radio frequency chain as may be used by an active device.

[0077] A semi-passive device may be configured to not transmit actively. For example, a semi-passive device may only transmit once it has been excited or has harvested sufficient energy to meet a power requirement. A semi-active device may include means for storing harvested energy, e.g., in a battery or another type of capacitor. In a semi-active device, the means for storing harvested energy may not be used to supply power for transmissions themselves, but rather may be used for other reasons such as supplying power to a processor or other circuitry.

[0078] An active device may refer to a device that requires power to operate and is capable of amplifying, switching, or modifying electrical signals. Active devices may perform signal processing through functions such as amplification, filtering, and conversion. These devices may be necessary for processing signals that have been converted to baseband, which is the range of frequencies a signal occupies before it is modulated onto a carrier frequency for transmission. Unlike passive devices, which may not require an external power source for basic operation, active devices may rely on an external power supply or a local energy source (such as a solar cell or battery) for transmission. Common examples of active elements include transistors, operational amplifiers, integrated circuits, and oscillators.

[0079] In some examples, a device as referred to herein (also referred to herein as an IoT device) may be a passive radio device, a semi-passive radio device, or an active device. The device may be a passive device that does not include any active elements, or it may be an active device that has both a power source (e.g., an internal or external power source) and one or more active elements. In some examples, the device may include both passive and active elements. It should be understood by those of skill in the art that the methods and procedures disclosed herein are not limited to a specific type of device (i.e., passive, semi-passive, or active) but may be applicable to any of these types of wireless devices. The terms “backscattering,” “reflecting,” and

“transmitting” may be used interchangeably herein. As used herein, the term backscattering may be used to interchangeably refer to a combination of actions undertaken by a receiver such as receiving and transmitting a signal, receiving and reflecting a signal, reflecting a signal, or simply transmitting a signal.

[0080] As used herein, the term backscattering may include or imply the decoding of an incoming signal, potentially in combination with other steps as referenced above. For example, backscattering may refer to receiving, decoding, and transmitting a signal; receiving, decoding, and reflecting a signal; decoding and reflecting a signal; decoding and transmitting a signal; or simply decoding a signal.

[0081] As used herein, the term backscattering may include or imply the modulation of an incoming signal, potentially in combination with other steps as referenced above. For example backscattering may refer to receiving, modulating, and transmitting a signal; receiving, modulating, and reflecting a signal; modulating and reflecting a signal; modulating and transmitting a signal; receiving and modulating a signal; decoding, modulating, and transmitting a signal; receiving, decoding, modulating and reflecting a signal; decoding, modulating, and reflecting a signal; decoding, modulating and transmitting a signal; or simply modulating a signal.

[0082] In some examples, backscattering may be referred to separately from, or in addition to, other actions undertaken by a device. For example, a device may be configured to receive and backscatter a signal; decode and backscatter a signal; backscatter and modulate a signal; backscatter and transmit a signal; receive, backscatter, and modulate a signal; receive, backscatter, and reflect a signal; modulate, backscatter, and reflect a signal; modulate, backscatter and transmit a signal; receive, backscatter, and modulate a signal; decode, backscatter, modulate, and transmit a signal; receive, decode, backscatter, modulate and reflect a signal; decode, backscatter, modulate, and reflect a signal; decode, backscatter, modulate, and transmit a signal; or receive, decode, backscatter, reflect, modulate, and transmit a signal.

[0083] In some methods, transmissions (e.g., from an interrogator to a device (e.g., an IoT device) or from a device (e.g., an IoT device) to an interrogator) may be organized into or performed during defined time intervals such as frames, slots or other types of time intervals. A cycle (e.g., an inventory round) may be defined as a group of time intervals during which the interrogator and devices exchange messages. Some methods disclosed herein may still be applicable if transmissions are not organized into defined time intervals; however, it may be assumed for the clarity of presentation that transmissions may be performed on a frame-basis.

[0084] One or both of the following conditions may apply. In some cases, the duration of a time interval (e.g., a frame) may not be fixed. The start of the time interval may be indicated with a predefined signal and/or a message. For example, a cycle may be organized into frames and the first frame may start with a first message. This may mean that a device may determine the time interval (e.g., for the frame) from when the message is sent or from when the message is received. For example, the time interval may start from T_1 + offset and end at T_2 , where T_1 may be the time instance of the last sample of the first message and T_2 may be the time instance of the first sample of the second message. The offset may be preconfigured, configured, or

determined by a device through other methods. The subsequent time intervals may start with the first message or a second message. It should be noted that, as mentioned above, the time interval between the first and second message may not be defined or labeled as a 'frame' yet the methods described herein may still be applicable.

[0085] In some cases, the duration of a time interval may have a fixed value. In some cases, the duration of the time interval may be fixed, but there may be several possible duration values, for example, for different numerologies and/or carrier frequencies. The start of a time interval may be indicated with a signal and/or a message.

[0086] In some methods, a device may randomly select a time interval during which the device may attempt to gain access to the channel; for example, the device may transmit a signal and/or a message during the selected time interval to establish a communication channel with the interrogator.

[0087] In some methods, the total number of time intervals (e.g., in a cycle) may be predefined and/or indicated, such as in a message (which may be, for example, the first message of a cycle). The corresponding number/index of a time interval may be indicated in a message, for example, at the beginning of a time interval. The number of time intervals in a first and second cycle may be different. In some methods, a 1-bit indication may be used to indicate/point the first time interval, for example the first time interval in a cycle.

[0088] A device may transmit a preamble (e.g., a preamble for random access) in a time interval. The device may be allowed to transmit a specific type of preamble (e.g., a short preamble or a long preamble, a preamble generated at the device, or a preamble generated at the interrogator and reflected by the device) in a specific time interval(s) (e.g., frame(s)) only. For example, the device may be expected to transmit or may transmit a short preamble in a first time interval and the device may be expected to transmit or may transmit a long preamble in a second time interval.

[0089] An m-bit codepoint (e.g., $m = 1$) in a message may indicate the time interval type. The m-bit indication may be transmitted per time interval (e.g., in a cycle) or in one time interval (e.g., the first frame in a cycle) and may be applicable to all time intervals in the same cycle.

[0090] One or more parameters may be included in a control message. A control message may include an identifier or identification of a first time interval in a cycle. For example, a 1-bit identification may be provided as follows. A value of 1 may indicate that a current time interval is the first time interval. A value of 0 may indicate that the current frame is not the first time interval.

[0091] A control message may include an indication of a number of time intervals in the cycle, which may be denoted by N bits. A control message may include a frame index, which may be denoted by M bits. In some cases, the M-bits may indicate a preamble length allowed in the current time interval, or one or more preamble lengths allowed in multiple different time intervals. This may be generalized to include a preamble length/type or other attributes. If the attributes apply to all the time intervals in a cycle (or to all the time intervals in which

preamble transmission is allowed), the M-bits may be transmitted in a control message at the beginning of a cycle.

[0092] The contents of the message in the first time interval of the cycle and the messages in the other time intervals may be different. For example, in some cases, only messages in the first time intervals may contain bitmaps for all preambles in the cycle. In some examples, only messages in a first time interval may indicate the number of frames in the cycle.

[0093] Some solutions may involve preamble backscatter power boosting. An overall summary of some of these solutions may be understood as follows. A device (e.g., IoT device) may receive (e.g., from an interrogator) a transmission. The transmission may include one or both of a signal and control information (e.g., in a message). In some cases, more than one transmission including a signal and/or control information may be transmitted by the interrogator. The signal may be an unmodulated carrier wave (CW). The control information may include one or more of: an indication to enable/disable power boosting, a power boosting value/level, and/or a repetition factor. The signal and the control information may be sent in separate transmissions. Control information may be received before or after a signal. The device may reflect a received signal, modulate it using a preamble, and use power boosting or repetition based on the energy level of the device.

[0094] If an energy level of the device (e.g., stored energy, battery level, etc.) is sufficient for transmitting with power boosting (e.g., with the indicated power boosting value/level) or is above a threshold, the device may modulate the received signal (the received CW) with a preamble and transmit the modulated signal using a first power level + a power boosting value/level (e.g., the indicated power boosting value/level). The device may select a preamble sequence (e.g., randomly) and/or may select a cyclic shift (e.g., randomly) for the preamble.

[0095] If an energy level of the device is not sufficient for transmitting with power boosting (e.g., with the indicated power boosting value/level) or if the energy level is below the threshold, the device may modulate the received signal with the preamble and transmit the modulated CW multiple times (e.g., the device may repeat the transmission multiple times) using the first power level for each transmission. The number of times the device transmits the modulated signal may be determined, for example, based upon the control information. In some cases, the number may be based on or equal to a repetition factor indicated by the control information.

[0096] The device may receive a message (e.g., a message replying to the modulated CW) that indicates the preamble (or the cyclic shift of the preamble) used by the device for modulation. When the device receives a message indicating the preamble (or cyclic shift) used by the device, the device may send an ID and optionally an energy level of the device (e.g., the current energy level of the device). Use of power boosting may be conditioned on the control information indicating that power boosting is enabled. In some cases, such as when power boosting is not enabled, the device may use repetition (e.g., the device may repeat the transmission of

the modulated CW multiple times based on the indicated repetition factor and, in some cases, may use the first power level for each transmission).

[0097] It should be understood that an energy level may be defined in terms of absolute energy (e.g., Joules) and/or relative energy (e.g., a ratio of the energy to the energy storage capacity such as 25%, 50%, etc.) Other ways to characterize the available and/or stored energy may be possible and may still be carried out in accordance with the methods disclosed here.

[0098] A multiple access scheme may be defined as a method and/or set of procedures that may be used by an interrogator and a device (e.g., an IoT device within a group of IoT devices) to establish a communication channel through which signal(s) may be exchanged. In the following paragraphs, a multiple access scheme is described.

[0099] One step of the procedure may be understood as follows: in some methods, a device may select a time interval (e.g., one of the time intervals in an inventory round) in which the device may attempt to get access to the channel and/or establish a communication channel with the interrogator. The selection may be random; for example, the device may choose one of the time intervals (from a group of time intervals) randomly and with equal probability. In some methods, the device may be configured and/or indicated a specific time interval. As one step of a random-access procedure, the device may transmit a preamble to the interrogator. The preamble may contain at least one sequence. A sequence as referred to herein may be a Zadoff-Chu sequence, m-sequence, Golay sequence, or another type of sequence.

[0100] In the following, a preamble may be defined to include a cyclic prefix (CP), a sequence, or k-repetitions of a sequence (e.g., where k is an integer and $k > 1$) and a guard interval (GI). However, a preamble may be formed in alternative forms or formats; for example, in some cases, a preamble sequence may not have a guard interval. A carrier wave modulated by the preamble sequence may be referred to as a "preamble." The methods disclosed herein may still be applicable if a signal other than a preamble is used, e.g., a reference signal, a positioning reference signal, etc.

[0101] FIG. 2 is a diagram illustrating an example of two preamble sequences of different lengths. As shown in FIG. 2, a first preamble 210 has a first format of length t_1 μ s and includes a cyclic prefix (CP) 211, four sequence repetitions 212a, 212b, 212c, and 212d, and a guard interval (GI) 213. A second preamble 220 has a second format of length t_2 μ s and includes a CP 221, two sequence repetitions 222a and 222b, and a GI 223. In some cases, the first format may be referred to as a "long" preamble format and the second format, being shorter than the first format, may be referred to as a "short" preamble format.

[0102] In some methods, the device may receive an unmodulated carrier wave, modulate it with a preamble sequence to generate a preamble, and backscatter the preamble. The modulation format may be one of ASK, FSK, PSK, etc. In some methods, the interrogator may modulate an unmodulated carrier wave with a preamble sequence, generate the preamble, and transmit the preamble. A device (e.g., an IoT device) may backscatter the received preamble after further processing. One difference between the former methods and the latter

methods may be that some devices may not be capable of generating or may not be expected to generate certain signals. For example, some device may be unable to generate or may not be expected to generate a signal modulated with a sequence of complex coefficients (e.g., a Zadoff Chu sequence).

[0103] At least one step of a procedure for channel access in a multiple access scheme may be understood from the following paragraphs.

[0104] Certain properties of the preamble and/or the preamble sequence may be configured and/or indicated to the devices. Additionally, or alternatively, properties of the transmission of the preamble and/or the preamble sequence may be configured and/or indicated to the devices. The indication(s) concerning the preamble and/or the preamble sequence, or concerning the transmission of the preamble and/or preamble sequence may be included in control information within a control message transmitted by the interrogator. A control message may be transmitted before a preamble (e.g., with a defined timing offset between the control message and the preamble) in a defined time period (e.g., in the first frame of an inventory round, and/or in every frame of an inventory round). There may be more than one type of control message. For instance, the contents of a first type of message may be partially or wholly different from the contents of a second type of message. Alternatively, or additionally, the control message may be received from another node, other than the interrogator. In some methods, multiple control messages may be sent or received, from different nodes.

[0105] An unmodulated carrier wave may be transmitted before a control message (and/or after a control message, in some methods), for example, to charge the storage units of the devices. It should be noted that the carrier wave may be transmitted by the interrogator even when the interrogator is not transmitting data or other signals on a channel so that the devices may perform backscattering.

[0106] A control message may include control information and may contain one or more of the following information and/or indications, e.g., destined for the devices. For example, the control message may indicate the start of a time interval (e.g., a frame) during which one or more of the devices may attempt to gain access to the channel, e.g., send a random-access preamble and/or a data message. The time interval may begin from the start of the message or the end of the message, or some predefined time interval following the start/end of the message. A device may determine a boundary (e.g., a start or end) of the time interval from the control message.

[0107] A control message may indicate a selection of a subset of devices. For instance, the message may contain control information to select a subset of the devices. The selected subset of the devices may be allowed to attempt multiple access, for example during the duration of the time interval or during the duration of multiple time intervals (e.g., during an inventory round). The subset selection may be based on an device ID, a flag being maintained at a device, an attribute of a device, or based on some other information. For example, certain time intervals may be allocated for transmission by the devices that have energy storage and/or power boosting capability.

[0108] A control message may indicate a preamble length and/or preamble sequence length and/or an indication to a length and/or an attribute of a length. For example, a codepoint in the message may indicate one or more lengths (for example, N1 seconds or symbols, and N2 seconds or symbols) and/or may indicate a short and/or a long preamble. In another example, the number of repetitions k of the sequence may be indicated.

[0109] A control message may indicate a number of repetitions or maximum number of repetitions of a sequence in the preamble. A control message may include an indication to enable/disable power boosting by the devices during the time interval or a group of time intervals. A control message may include an indication of a power boosting value/level (or a maximum value/level) that may be applied by the devices (e.g., when allowed).

[0110] A control message may include an indication of an index of the time interval, such as a frame number. A control message may include one or more delay values or an indication based upon which one or more devices may determine the delay values. For example, a codepoint in the message may indicate a delay value or a group of delay values. In some examples, the message may indicate a maximum value for delay, a minimum value for delay (zero delay may be assumed if not indicated) and the number of delay values. Using this information, a device may determine the possible set of delay values as $\text{minimum delay} + k * \text{offset}$ where $\text{offset} = (\text{maximum delay} - \text{minimum delay}) / \text{number of delay values}$.

[0111] A control message may include an indication whether a transmission (e.g., a transmission following the control message) contains a preamble. Another case may be that the transmission is an unmodulated carrier wave, and the device may be expected to modulate it to generate the preamble.

[0112] In some methods, a message may include an indication whether to backscatter the incoming signal without modulating it. For example, a bit value of 1 may indicate "backscatter without modulation", and a bit value of 0 may mean "modulate with preamble sequence and backscatter".

[0113] A control message may include an indication of a transmit power of the interrogator or an indication associated with an attribute of the transmit power. For example, the control message may indicate whether transmit power may further be increased (e.g., in a future retransmission of a preamble). For example, the control message may indicate the transmit power difference between this transmission and another transmission (e.g., a data transmission), or if transmit power may further be increased (e.g., during a data transmission).

[0114] A control message may include an indication of a time gap or an attribute of the time gap between a message and the preamble transmission. For example, during this time gap, an unmodulated carrier wave may be transmitted.

[0115] A control message may include an indication of interrogator ID or an attribute of the ID or information that may be used to identify the interrogator.

[0116] A control message may include an indication of a coverage mode for the time interval or group of time intervals. For example, the control message may include an indication of whether the device should operate in a coverage enhanced mode or not. In some examples, in a coverage enhanced mode, long preambles may be used. In some examples, in a coverage enhanced mode, repetitions of data messages may be used. In some examples, in a coverage enhanced mode, power boosting by the devices (if such devices are capable of power boosting) may be expected.

[0117] In some examples, a device may receive and decode the message and the device may determine to attempt channel access. For example, the device may select a time interval (e.g., a frame) randomly from a group of available time intervals determined from a control message and/or configuration and/or a received indication. The device may select a time interval based on received signaling or configuration information or based on a stored configuration. For example, it may have received an indication to attempt channel access in the current time interval.

[0118] The device may determine to attempt access at least based on the preamble type and/or preamble attributes allowed in a time interval. For example, the device may determine to attempt channel access based on the preamble length. In some methods, if the preamble is a long preamble, it may determine to attempt channel access, and if the preamble is a short preamble it may determine to postpone channel access attempt. The device may determine to access the channel if the preamble is not an unmodulated carrier wave, e.g., if it is a preamble signal (i.e., a signal that contains a preamble).

[0119] The device may further determine the time interval from the preamble type and/or the preamble attributes. For example, the device may choose a first time interval(s) for short preamble and a second time interval(s) for long preamble.

[0120] Further steps of a channel access procedure may be understood as follows. A device may receive or may determine to receive a preamble. The device may determine to attempt channel access in the current time interval (e.g., a frame). In some methods, the device may backscatter a received preamble. The device may apply a delay to the received preamble before backscattering the preamble. The value of the delay may be selected randomly, e.g., from a set of predefined delay values. In some methods, the delay value may be determined, for example, from a prior configuration, signaling, or usage. The device may be able to determine the starting time of the preamble using the fixed timing offset between the message and the preamble. The delay value may be measured in seconds, number of symbols, or by some other time duration or interval. In some methods, the delay value may be determined based on previously selected delay value(s) of prior channel access attempts. For example, the device may maintain a delay value for a configured time period. The device may fall back to random selection when the time period expires.

[0121] The application of a delay with a duration or value of D may be performed as follows. The device may determine the start of the preamble. For example, during the first D seconds (assuming D is measured in seconds) the device may adjust a load impedance accordingly so that the incoming signal is not backscattered.

After D seconds of the preamble signal, the device may readjust the load impedance accordingly so that the incoming signal is backscattered. The device may be configured, may receive an indication, or may determine, to increase the power of the backscattered signal, e.g., by applying power boosting. In some examples, the device may apply a cyclic shift to the preamble and then backscatter the cyclically shifted preamble.

[0122] In some methods, the application of a delay with a duration or value of D may be performed as follows. The device may determine the start of the preamble. The device may modulate the preamble with a modulation signal. The modulation signal may be, for example, a square wave with a specific periodicity. The device may introduce a cyclic shift or delay to the modulating signal (e.g., the square wave) and modulate the preamble with the modulating signal. The modulated preamble may then be subject to backscatter modulation.

[0123] FIG. 3 is an example of a timing diagram illustrating a signal that may be used to modulate a preamble in accordance with one or more methods described herein. In the example shown in FIG. 3, square wave $s_1(t)$, illustrated by element 310, has a periodicity of T seconds, and the duration of the square wave is eight periods. The square wave 310 alternates between values "0" and "1". It should be noted that the duration of the square wave may, in some example, be the same as the duration of the preamble. FIG. 3 further illustrates the introduction of a cyclic shift of $D = T/2$ seconds to the square wave $s_1(t)$, which results in a modulated signal $s_2(t)$, illustrated by element 320. The cyclic shift may be applied from the right or the left.

[0124] After the preamble is multiplied by the modulating signal, the resultant signal may be subject to backscatter modulation. For example, in cases where OOK modulation is used, the portion(s) of the preamble multiplied by the value "1" of the modulating signal may be backscattered and the portion(s) of the preamble multiplied by the value "0" of the modulating signal may not be backscattered. For example, the portions of the signal that are not backscattered may be absorbed by the device.

[0125] Methods described herein may similarly apply if the delay D is introduced to the modulating signal. The cyclic shift and/or delay may be applied to the preamble and/or a signal modulating the preamble. It should be noted that a cyclic shift may be viewed as a delay or advance of a signal and the terms cyclic shift, delay, and advance may be used interchangeably.

[0126] FIG. 4 is a diagram illustrating an example of a method for backscattering preamble transmissions. In FIG. 4, the propagation of signals over time is illustrated along a horizontal or 'x'-axis, from left to right. Signals and/or messages transmitted by an interrogator 410 and two devices, Device 1 (denoted in FIG. 4 by element 420) and Device 2 (denoted in FIG. 4 by element 430), are shown. For example, as shown at 411, the interrogator transmits a control message (shown at 311 and 317), in accordance with embodiments described in paragraphs above. As shown in FIG. 4, the interrogator 410 transmits a preamble 412. Device 1 receives the preamble, applies a delay of D1 and performs backscattering as shown at 421. The interrogator 410 receives the backscattered preamble and sends a reply to Device 1. Device 2 receives the preamble, applies a delay of D2 and performs backscattering as shown at 431. The interrogator 410 transmits the preamble 412

using a carrier wave (CW) as denoted in FIG. 4. The delays may be applied to the preamble and/or the modulating signal as described before.

[0127] In some methods, a device may reflect a portion of the preamble. For example, an interrogator 410 may send a first preamble sequence including N symbols twice (1 ... N, 1 ... N) and a device may reflect only part of the symbols (e.g., x ... N, 1 ... x-1).

[0128] Another step of the channel access procedure may be understood as follows. Upon transmission of the preamble, the device may monitor for a reply message from the interrogator 410. The monitoring occasions (e.g., the time during which the device should monitor) may be known by the device and/or predefined.

[0129] Upon reception of the reply message, the device may, from the message, determine an indication of one or more delay values, D1, D2, D3, and so forth. For example, there may be 2^n possible values of D (e.g., signaled or indicated by the interrogator) and the reply message may contain n bits wherein each codepoint may indicate one of the D values. In one example, bits 00 may correspond to D0; bits 01 may correspond to D1; bits 10 may correspond to D2; bits 11 may correspond to D3. The reply message may contain an indication of one D value or more than one D value. If the indicated D value or one of the indicated D values matches the delay that the device had applied for the preamble transmission, then the device may determine that the preamble transmission was (possibly) successful.

[0130] For example, as shown in FIG. 4, it may be assumed that Device 1 applies delay D1 to the received preamble 411, that a second device applies delay D2 to the received preamble 411 and that they each transmit a delayed preamble as shown at 421 and 431. The interrogator may estimate D1 and D2 from the received aggregate signals 421 and 431. The interrogator 410 may indicate D1 and D2 in one or more reply messages, shown at 413 and 415, respectively. It should be noted that in some embodiments, a reply message may contain one delay value, and in some embodiments a reply message may contain more than one delay value.

[0131] It should be noted that it is possible for more than one device to choose the same delay value and transmit the same delayed version of the preamble. To prevent a possible collision in subsequent communications, a contention resolution phase may be used (as will be described below). Alternatively, or additionally, a collision may result in an unsuccessful subsequent communication and the device(s) may need to retransmit a preamble.

[0132] As described above, a device may receive a reply message from the interrogator that contains one delay value. If the delay value does not match the delay the that device had applied to the backscattered preamble, the device may continue monitoring for a reply message (e.g., another reply message). The device may continue comparing the delay value contained in reply messages with the delay that the device had applied to the backscattered preamble until all reply messages (e.g., in a cycle) are decoded.

[0133] If the delay value matches the delay the device had applied to the backscattered preamble, the device may transmit a message to the interrogator. In the context of FIG. 4, two of such messages transmitted by Device 1 and Device 2 are illustrated by elements 422 and 432, respectively. Each message may contain

an identification of the respective device. The ID may be a random number, or a number stored in the device memory. The message may contain capability information. For example, the capability information may relate to whether the device is capable of power boosting, information regarding the current energy level in the device's energy storage, data payload size, preferred modulation/coding scheme, or other information. In some methods, the message may contain data, for example a serial number or a sensor measurement data.

[0134] A message exchange between the interrogator and the device may continue until an indication is sent to the device from the interrogator or by the device to the interrogator that message exchange has ended. For example, an indication that the message exchange has ended may be one or more of a new reply message with a new D value, an ACK, a flag flipped by the interrogator at the device, a new control message (e.g., indicating a new frame has started), an indication from the interrogator to go into sleep mode (e.g., deactivate the device, permanently or temporarily), or another message or signal.

[0135] In some methods, the interrogator may send a message, such as an acknowledgement, to a device. In the context of FIG. 4, two examples of acknowledgement messages sent by interrogator 410 are illustrated by elements 414 and 416. The message may contain part, or all of the ID sent by the device. The message, or a portion of the message, may be scrambled with the ID or part of the ID. The message may contain scheduling information for the device. For example, the message may indicate to the device one or more time intervals (e.g., slot(s) or frame(s)) to use for data transmission.

[0136] Though not illustrated in FIG. 4, in some embodiments, the interrogator may send one or more "request" messages to one or more devices. A request message may contain the ID that was agreed upon or that was transmitted by the device. The request message may contain a request for data. For example, the request message may request a serial number, a measurement, or other information. In some embodiments, the request message may not request a specific type of data but may instead be an indication for the device to send the data it has. The request message may include resource allocation information (e.g., a slot allocation or another time resource allocation) for the device to send data.

[0137] In some methods, upon receiving a reply message and confirming the D value, the device may send data (e.g., a serial number, measurement data, etc.) and/or a device ID in a message. In the context of FIG. 4, two examples of data messages sent by Device 1 and Device 2 are illustrated by elements 423 and 433. In some methods, an acknowledgment message (e.g., such as the acknowledgement messages 414 and 416 shown in FIG. 4) may include a request for one or more devices to send further data such as an ID.

[0138] Contention resolution is described herein. For contention resolution, a device may send a message indicating an ID to the interrogator. To achieve this, multiple sub-time intervals may be defined. For example, k sub-time intervals may be allocated after the reply message. The locations of these time intervals may be known (e.g., predefined with reference to the reply message).

[0139] FIG. 5 is a diagram illustrating an example of a method for contention resolution. Signals and/or messages transmitted by an interrogator 510 and two devices, Device 1 (denoted in FIG. 5 by element 520)

and Device 2 (denoted in FIG. 5 by element 530), are shown. For example, as shown at 511 and 518, the interrogator 510 transmits control messages in accordance with embodiments described in paragraphs above. Similarly as in the example illustrated in FIG. 5, the interrogator 510 transmits a preamble 512. Device 1 receives the preamble, applies a delay of D_1 and performs backscattering as shown at 521. The interrogator 510 receives the backscattered preamble and sends a reply to Device 1, shown at 513. In the example shown in FIG. 5, Device 2 receives the preamble 512, applies a delay also equal to D_1 and performs backscattering as shown at 531. Because the same delay value D_1 is applied to the backscattered preambles 521 and 531, a collision, or contention, between the backscattered preambles may arise.

[0140] A device may select (e.g., randomly) one or more sub-time intervals and send an ID message in the selected one or more sub-time intervals. The number of sub-time intervals may be indicated by the interrogator, for example, in a reply message or in a control message. For example, as shown in FIG. 5, there may be two sub-time intervals, 501 and 502. Device 1 transmits an ID message 522 in the first sub-time interval 501 and Device 2 transmits an ID message 532 in the second sub-time interval 502. The messages 522 and 532 may each contain an ID, part of an ID, and/or other data.

[0141] Similarly as described in paragraphs above, the interrogator 510 may send messages to acknowledge messages 522 and 532, as shown in FIG. 5 at 514 and 515 respectively. The devices 520 and 530 may each send data as shown at 523 and 533, which may be acknowledged by the interrogator as shown at 516 and 517. In some embodiments, as shown at 516 and 517, the interrogator may acknowledge the data 523 and 533 sent by Device 1 and Device 2.

[0142] Methods involving the use of multiple D values are described herein. In some methods, a reply message sent by an interrogator may include multiple D values for multiple detected preambles. A device that receives a message including a D value may determine that the preamble it had transmitted may have been received.

[0143] In such cases, the reply message may include scheduling information for the devices that transmitted preambles with delays corresponding to the D values. Alternatively, or additionally, an device may determine the time interval in which to send a message from the order of the D values in the reply message. For example, a device having transmitted a preamble with a delay corresponding to the first D value in the reply message may use the first slot to send an ID, and a device having transmitted a preamble with a delay corresponding to the second D value in the reply message may use the second slot to send an ID.

[0144] In some methods, the interrogator may send a scheduling message using a D value as the device ID. For example, a message may contain the D value, and a request for data. A device receiving the message and confirming the D value may gain access to the channel and transmit the requested data.

[0145] Further steps of the channel access procedure may be understood as follows. If the device does not receive a reply message indicating the first delay value (e.g., corresponding to a preamble of length L_1) used by the device, the device may carry out one or more steps as set for the in the paragraph below.

[0146] If the device does not receive a reply message indicating the first delay value (corresponding to a preamble of length L1) used by the device, the device may transmit a second preamble of length L1 (e.g., the CW modulated by the second preamble of length L1) with power boosting. For example, the device may apply a first power level plus the power boosting level or value to transmit the second preamble of length L1. In some methods, the device may transmit the second preamble of length L1 potentially after a back off period, e.g., in the next cycle. The transmission of a second preamble with power boosting may be conditioned upon the energy level of the device (e.g., stored energy, battery level, etc.) being sufficient for transmitting with power boosting (e.g., is greater than a threshold). The transmission of a second preamble may alternatively, or additionally, be conditioned upon whether power boosting is allowed (or not disallowed explicitly). The power boosting level or value, or the difference between the first power level and the power level when power boosting is applied may be signaled by the interrogator or predetermined or determined by the device. If some or all of the conditions for transmitting the second preamble with power boosting are not met, the device may, for example, not transmit a second preamble, transmit a second preamble without power boosting, or transmit a second preamble with a different length L2. Further details regarding the transmission of a second preamble are provided in paragraphs below.

[0147] The time interval (e.g., frame) in which to send the preamble may be selected randomly. The time interval chosen may be a time interval that supports a preamble length L1 (may be signaled in a control message).

[0148] The device may determine back off parameters according to one or more of the following methods. In some cases, a backoff period or time may be chosen as any time interval (e.g., frame) in the same cycle or in another cycle, e.g., the next cycle. In some cases, the device may receive a control message within one cycle that indicates backoff has been completed (for one or all devices). After this message is received, the device may choose one time interval from the remaining time intervals randomly. In some cases, a specific time interval is indicated for retrial, for example, in a control message such as the reply message.

[0149] In some embodiments, if the device does not receive a reply message indicating the first delay value (corresponding to a preamble of length L1) used by the device, and if the energy level of the device (e.g., stored energy, battery level, etc.) is not sufficient for transmitting with power boosting (e.g., is below the threshold), the device may transmit a preamble of a second length L2 (e.g., the CW modulated by the preamble of length L2). In some embodiments, L2 may be greater than L1, though it should be appreciated that in other embodiments L2 may be equal to L1, or less than L1. The device may transmit a preamble of length L2 without power boosting (e.g., using the first power level). In some embodiments, if power boosting is disabled (e.g., indicated as disabled by the control message), the device may transmit the preamble of the second length L2 without power boosting regardless of the energy level of the device.

[0150] The control information may include an indication whether preamble length L2 is used/allowed in one or more time intervals (e.g., frames) and the device may randomly choose one of the time intervals that support L2.

[0151] A determination whether the device is to use power boosting and/or longer preamble may be performed as follows. The device may transmit a second preamble of length L1 (e.g., the CW modulated by the second preamble of length L1) with power boosting. For example, the device may apply a first power level plus the power boosting level or value to transmit the second preamble of length L1. The device may transmit a second preamble with power boosting if power boosting is allowed (or not disallowed explicitly). The transmission of a second preamble with power boosting may be conditioned upon an energy level of the device (e.g., stored energy, battery level, etc.) being sufficient for transmitting with power boosting (e.g., the energy level is greater than a threshold). The power boosting level or value, or the difference between the first power level and the power level when power boosting is applied may be signaled by the interrogator or predetermined or determined by the IoT device. If some or all of the conditions for transmitting the second preamble with power boosting are not met, the device may, for example, not transmit a second preamble, transmit a second preamble without power boosting, or transmit a second preamble with a different length L2.

[0152] An overall description of solutions utilizing orthogonal preambles is provided herein. In some methods, a device (e.g., an IoT device) receives (e.g., from an interrogator) a transmission that includes a signal and control information (e.g., in a message). The control information may be received before the signal.

[0153] The control information may include one or more of: an indication of a start or a start time of a first time interval (e.g., a start or start time of a frame or slot), an indication to enable/disable power boosting, a power boosting value/level, or a preamble length (e.g., a first preamble length L1). The signal may include a first preamble (e.g., a carrier wave (CW) modulated with a first preamble). The length of the preamble may be the first preamble length L1. The preamble may include a cyclic prefix and one or more repetitions of a sequence. The preamble may be consistent with the description provided in paragraphs above.

[0154] In some methods, the device may transmit (e.g., by backscattering or reflecting) the received signal after applying a delay of a first value to the received signal. The device may transmit the received signal starting at a time corresponding to the indicated start (or start time) of the first time interval plus the first delay value. The device may select the first delay value randomly, e.g., from a set of values where the set of values may be configured, known, or received such as from the interrogator, or according to a non-random method (e.g., based on one or more determined, configured, or preconfigured criteria that may be evaluated by the device).

[0155] In some embodiments, the device may receive a reply message that may indicate the first delay value used by the device. When the device receives a reply message indicating the first delay value used by the device, the device may send an ID associated with the device (e.g., to the interrogator).

[0156] In some embodiments, the device may send the ID in a second time interval. The device may select the second time interval (e.g., randomly) from a set of time intervals (e.g., that may be known or configured) that follow the reception (e.g., that follow a time or time unit of the reception such as the start or end time or time unit of the reception) of the reply message.

[0157] If the device does not receive a reply message indicating the first delay value used by the device, the device may carry out one or more of the following steps. In some steps, if the energy level of the device (e.g., a stored energy, battery level, etc.) is sufficient for transmitting with power boosting (e.g., is greater than a threshold), the device may transmit a second preamble of length L1 (e.g., the CW modulated by the second preamble of length L1) with power boosting (e.g., using a first power level plus the power boosting level or value). In some steps, if the energy level of the device (e.g., stored energy, battery level, etc.) is not sufficient for transmitting with power boosting (e.g., is below the threshold), the device may transmit a preamble of a second length L2 (e.g., the CW modulated by the preamble of length L2). L2 may be greater than L1, though it should be understood that in some embodiments, L2 may be equal to L1 or less than L1. The device may transmit the preamble of length L2 without power boosting (e.g., using the first power level).

[0158] In some steps, if power boosting is disabled (e.g., indicated as disabled by the control message), the device may transmit the preamble of the second length L2 without power boosting regardless of the energy level of the device. If the device transmits the ID, the device may receive an acknowledgment message confirming receipt of the ID. For example, the acknowledgement message may contain the ID or a portion of the ID.

[0159] In some embodiments, if the device transmits the ID and does not receive an acknowledgment message confirming receipt (e.g., the acknowledgement message does not contain the ID or a portion of the ID, or the device does not receive any acknowledgment message), the device may transmit (e.g., backscatter or reflect) a (e.g., a second or third) preamble of length L1 (e.g., a CW modulated with the preamble of length L1).

[0160] In some methods, the device may receive a message (e.g., containing control information) and the device may receive an unmodulated carrier wave. The device may modulate the carrier wave with a preamble sequence and backscatter the modulated carrier wave.

[0161] A preamble sequence (also referred to herein as simply a "sequence") may contain one or more of the following: a cyclic prefix, a sequence or repetitions of a sequence, or a guard interval. One or more coefficients of a sequence (e.g., symbols) may be 1 and -1 (or 1 and 0). In some embodiments, a device may select a preamble sequence (e.g., randomly) from a set of possible preamble sequences. In some embodiments, the preamble sequence may already be stored at the device (e.g., during manufacturing). One sequence, or a set of sequences, may be available (e.g., stored in a memory) at the device, and the device may generate the preamble sequence, for example by applying a specific number of repetitions to the sequence, adding the cyclic prefix and the guard interval. The device may select a preamble (e.g., randomly) or may select a cyclic shift (e.g., randomly) for the preamble. The terms "preamble index" and "cyclic shift index" may be used interchangeably.

[0162] In some methods, the device may transmit one preamble sequence and/or multiple repetitions of the sequence, for example, to enhance coverage. In some methods, the device may adapt the symbol duration.

For example, in one case, a symbol duration of the preamble may be equal to t_1 (e.g., a duration equal to t_1 seconds and in another case the symbol duration may be equal to t_2 (e.g., t_2 seconds). In some methods, the symbol duration may be defined in terms of a clock signal. For example, a symbol duration may be represented by the variable M , where $M = 2$ clock symbols, or $M = 4$ clock symbols, etc., and where one clock symbol may correspond to a square wave. In some methods, a longer symbol duration may be used to enhance coverage.

[0163] In some methods, a control message may indicate one or more of the following information: a maximum number of repetitions the device may apply, a number of repetitions the device may apply, or a symbol length (e.g., in terms of multiple of a clock signal, M).

[0164] In some methods, the device may determine to transmit a preamble in an enhanced coverage mode. For example, the preamble may not have been detected by the interrogator (for example the device may not receive a reply message) in a first transmission and in a second transmission the device may make a determination to transmit in an enhanced coverage mode.

[0165] In some methods, if an energy level of the device (e.g., stored energy, battery level, etc.) is sufficient for transmitting with power boosting (e.g., transmitting a preamble with the indicated power boosting value/level) or is above a threshold, the device may modulate the received signal (i.e., the received CW) with a preamble and transmit the modulated signal using a first power level while applying or adding a power boosting value/level (e.g., the indicated power boosting value/level).

[0166] A determination whether to boost the power may be based on one or more of the following. For example, the determination whether to boost the power may be based on whether the device has sufficient power in the storage for power boosting. The determination of whether to boost the power may be based on whether the device has received control information that has enabled and/or indicated power boosting and/or repetitions. The determination of whether to boost the power may be based on whether a previous random-access attempt was successful or unsuccessful. The determination of whether to boost the power may be based on a priority relative to other techniques or procedures. For example, power boosting may have a higher priority than another technique such as repetition or using longer symbols (for example, in accordance with some sets of defined rules or received configuration or indication, a device may first apply power boosting before resorting to using repetitions).

[0167] During an initial random-access attempt, a device may apply an M value and/or number of repetitions indicated in a control message. If random-access is not successful, then the IoT device may retransmit a preamble in another time interval. In some methods, the retransmission may be performed potentially in another cycle or in the same cycle after a backoff period. This may be configured by the interrogator or enabled/disabled. In this attempt (i.e., in the retransmission), the device may also boost power if it has sufficient energy; if it does not have sufficient energy, it may increase M and/or the number of repetitions.

[0168] The methods in previous sections may apply with the difference that in this method, the device may generate the preamble, generate multiple repetitions of a signal and/or a message, and/or change a modulation

scheme so that one symbol is transmitted over a longer or shorter duration. For example, when the modulation scheme is changed, the symbol duration is longer or shorter depending on the scheme.

[0169] In some methods, a device may transmit data and/or a message to the interrogator without first transmitting a preamble. The device may choose a time interval (e.g., randomly choose a frame among the allowed frames) and may perform one or more of the following steps. For example, the device may transmit a message that may contain at least one of an ID or user data (e.g., a sensor measurement). The device then may monitor for an acknowledgement message. The acknowledgement message may contain part or all of the ID. An attribute of the acknowledgement message may be defined by part or all of the ID. For example, a CRC included in the acknowledgement message may be scrambled with part or all of the ID.

[0170] The device may transmit a message that may contain at least user data (e.g., one or more sensor measurements). The device then may monitor an acknowledgement message. The acknowledgement message may contain part or all of the user data. One attribute of the acknowledgement message may be defined by part or all of the user data. For example, the CRC may be scrambled with part of the user data (e.g., last N bits of the data). The acknowledgement message may contain a request for additional data (e.g., user ID) transmission from the device.

[0171] A determination whether to transmit a preamble may be made based on a configuration, signaling, or indication received, for example, in a control message. For example, a control message in the first time interval (e.g., frame) of a cycle may enable/disable preamble transmission. In some examples, the preamble transmission(s) may be enabled/disabled per time interval (e.g., frame) or group of time intervals in a cycle. In some examples, the type of preamble may be indicated per time interval or group of time intervals in a cycle: the first N/4 time intervals may be allocated for backscattered preambles, the second N/4 time intervals may be allocated to generated preambles, and/or the last N/2 time intervals may be allocated for transmission without preambles.

[0172] Some solutions described herein may concern coverage enhancements.

[0173] In some embodiments, a first device (e.g., an interrogator device or WTRU) receives configuration information from a network node (e.g., a base station or a nodeB (e.g., a gNB)) including one or more of: a maximum transmit power of the first device towards one or more other devices (e.g., which may be a type of device such as an IoT device); a maximum transmit power of the one or more other devices; an indication of whether power boosting is allowed or enabled (e.g., for the one or more other devices); a signal quality/strength threshold; a maximum number of repetitions (e.g., for the one or more other devices); or a priority of energy conservation (e.g., for the one or more devices).

[0174] The first device may transmit a first transmission with a first transmit power to at least a second device (e.g., a device from among the one or more other devices or a device of the type of the one or more other devices). The first device may receive a second transmission from the second device. The second transmission may include a modulated carrier wave and/or a preamble (for example, the received second

transmission may be a reflection or backscatter of the first transmission). The received second transmission may include information regarding whether the second device supports power boosting and/or whether the second device applied power boosting for the second transmission. The first device may determine (e.g., measure or estimate) a received signal quality or strength, such as an RSRP of the received second transmission.

[0175] In some examples, if the determined signal quality or strength is below the signal quality/strength threshold, the first device may do one or more of the following. The first device may determine a power headroom as a difference between the maximum transmit power of the first device towards one or more other devices and the first transmit power. If the power headroom is above a threshold (i.e., if there is enough headroom), the first device may determine a second transmit power that is higher than the first transmit power and may transmit a third transmission (e.g., carrier wave and/or preamble) to the second device using the determined second transmit power. If the power headroom is below the threshold (i.e., there isn't enough headroom), the first device may send a transmission to the second device indicating to boost power and/or indicating a number of repetitions to use for transmission.

[0176] In some examples, the first device may determine whether to increase its power for transmission or to indicate to the second device to increase its transmit power or use repetitions. The determination may be based on one or more of the received configuration information and/or a size of a payload to be transmitted by the second device. If the first device determines to increase its power for transmission, the first device may determine a second transmit power that is higher than the first transmit power and transmit a third transmission (e.g., carrier wave and/or preamble) to the second device using the determined second transmit power. If the first device determines to indicate to boost power and/or use repetitions, the first device may send a transmission to the second device indicating to boost power and/or indicating a number of repetitions to use for transmission.

[0177] In some methods, the interrogator may receive configuration information from the network. For example, if the interrogator is a WTRU, it may receive configuration information from a base station (e.g., a nodeB such as a gNB). The configuration information may include, but may not be limited to, one or more of the following: a maximum transmit power for the interrogator towards one or more other devices that may be a type of device such as an IoT device; a total maximum transmit power for the interrogator; a maximum transmit power of the one or more devices; an indication of whether power boosting is allowed or enabled (e.g., for the one or more other devices); a signal quality/strength threshold (e.g., including RSRP, SNR, SINR, etc.), which may be measured from the signal(s) received from the devices; a maximum number and/or number of repetitions (e.g., for the one or more other devices) applicable to the transmission by an device of a signal and/or on a channel; or a priority level associated with the interrogator and/or the device. In some methods, the priority level may characterize the priority or relative priority of energy conservation. For example, energy conservation at the device may have higher priority than energy conservation at the interrogator. The

interrogator, based on the priority, may determine one or more transmission parameters, e.g., a transmission power of the interrogator and/or the device.

[0178] In some methods, a priority may be determined by the interrogator, e.g., based on one or more rules. In some examples, a device may always have higher priority. In some examples, the device may have higher priority only if the energy level of the interrogator is above a certain level. In some examples, the device may have a higher priority only if the energy level of the device is below a certain level.

[0179] Substantially as described in paragraphs, above, an energy level may be defined in terms of absolute energy (e.g., Joules) and/or relative energy (e.g., a ratio of the energy to the energy storage capacity such as 25%, 50%, etc.) Other ways to characterize the available and/or stored energy may be possible and may still be carried out in accordance with the methods disclosed here.

[0180] In some methods, the interrogator may transmit a first transmission with a first transmit power to at least a second device (e.g., an IoT device from among the one or more other devices or a device of the type of the one or more other devices). The first transmission may be a transmission of an unmodulated carrier wave, a preamble (e.g., a preamble to be backscattered by the IoT devices as discussed previously, etc.), a reference signal, a message, or another type of signal.

[0181] The interrogator may receive a second transmission from the device. The second transmission may include a modulated carrier wave and/or a reflection or backscatter of the first transmission (e.g., a reference signal transmitted by the interrogator and backscattered by the device). The received second transmission may include information regarding whether the second device supports power boosting and/or whether power boosting is applied for the second transmission. The received second transmission may include an attribute of the energy level at the storage of the device. For example, the attribute may be the ratio of available energy to the storage capacity and/or total storage capacity.

[0182] In some methods, the interrogator may determine (e.g., measure or estimate) a received signal quality or strength, e.g., an RSRP of the received second transmission.

[0183] In some methods, the interrogator may increase and/or determine to increase the transmission power towards one or more devices. The determination may be based on one or more conditions that may include at least one of, but is not limited, to those described in the following paragraphs.

[0184] In some methods, the interrogator may determine a power headroom as a difference between the maximum transmit power and a reference transmit power wherein the reference transmit power may, for example, be the transmit power applied to the signal that was backscattered by the IoT devices and used for RSRP measurement at the interrogator. The reference transmission power may be the last transmission power applied. The reference transmission power may be the transmission power applied in a specific time interval.

[0185] In some methods, the interrogator may compare the difference between the power headroom and a threshold. The threshold may be configured by the network. If the difference is greater than zero, then the

interrogator may determine a new transmission power, e.g., $p = p_{\text{reference}} + p_{\text{offset}}$. The value of p_{offset} may be configured and/or indicated by the network.

[0186] In some methods, the interrogator may determine a priority (e.g., priority of energy conservation) and the priority of one or more devices may be determined to be higher. The interrogator may increase and/or determine to increase the transmission power towards one or more devices based on the priority of the interrogator and/or the one or more devices.

[0187] In some methods, the interrogator may increase and/or determine to increase the transmission power towards one or more devices if the energy stored at the device is below a threshold, or equal to or below a threshold.

[0188] In some methods, the interrogator may increase and/or determine to increase the transmission power towards one or more devices if the time it would take for the energy stored at the device to reach a certain level is more than a threshold, or equal to or greater than a threshold.

[0189] In some methods, the interrogator may estimate the number of devices. In some methods, the devices inventoried (e.g., the number devices that communicated with the interrogator and sent some data, such as a serial number) after the completion of one or more cycles may be less than the estimated number. This may mean that some devices were not able to access the channel, e.g., due to collisions and/or coverage issues. The interrogator may increase the transmission power until all devices are inventoried and/or until the estimated number of devices to be inventoried is zero or below a threshold.

[0190] In some methods, the interrogator may determine to request from and/or indicate to the device to increase or boost its transmission power. The determination may be based on one or more conditions that may include, but may not be limited to, at least one of the following. One condition may be that the interrogator has reached maximum transmission power. The power boost request/indication may be transmitted in a common message to a group of devices. The devices receiving the message/indication may apply the increased power to their transmission. The increased transmission power may be applied until the energy level falls below a threshold. The amount of power increase may be indicated to the IoT devices.

[0191] The interrogator may request an device to boost power and/or use repetitions and/or use longer symbols (i.e., apply a different MCS). The device may send its energy level in a message. If the energy level is above a threshold, then the interrogator may request the device to use power boosting. The interrogator may signal to the device to charge its storage unit, e.g., a capacitor. For example, a 1-bit value may signal to the device that a CW will be transmitted for the next k ms or until the next message. The signal may indicate to the device to stop monitoring the channel and recharge the energy storage unit.

[0192] FIG. 6 is a flow diagram further describing an example of a procedure, which may be performed by a device, for backscattering signals. As shown in FIG. 6, at 610, the device receives at least one transmission including a signal (e.g., a CW) and/or control information. The control information may include, for example, one or more of an indication to enable or disable power boosting, an indication of a power boosting value, or a

repetition factor, though it should be appreciated that the control information referred to in FIG. 6 may include control information as discussed in any of the embodiments referred to above. As shown at 620, the device may backscatter (i.e., reflect) the received signal, while modulating the signal using a parameter based on an energy level of the device. For example, if the energy level of the device is sufficient for power boosting or is above a threshold, the device may reflect the signal using power boosting. In some examples, if the energy level of the device is not sufficient for power boosting or is below a threshold, the device may reflect the signal multiple times. The parameter used to modulate the signal may be one of a preamble or a cyclic shift. As shown at 630, the device may receive a message (e.g., a reply to the backscattered signal) that includes an indication of a parameter used by the device to modulate the backscattered signal. The indication of the parameter used by the device to modulate the reflected signal may serve as an acknowledgement of the backscattered signal.

[0193] FIG. 7 is a flow diagram describing an example of a procedure, which may be performed by a device such as an interrogator, for enabling the backscattering signals and for receiving said backscattered signals. As shown in FIG. 7, at 710, the interrogator sends least one transmission including a signal (e.g., a CW) and/or control information. The control information may include, for example, one or more of an indication to enable or disable power boosting, an indication of a power boosting value, or a repetition factor. Subsequently, as shown at 720, the interrogator may receive at least one backscattered (i.e., reflected) repetition of the signal that it transmitted previously. The backscattered signal may be modulated based on a given parameter, such as a preamble sequence. The interrogator may, as shown at 730, send a message (e.g., a reply to the backscattered signal) that includes an indication of a parameter used by the device to modulate the backscattered signal. The indication of the parameter used by the device to modulate the reflected signal may serve as an acknowledgement of the backscattered signal.

[0194] FIG. 8 is flow diagram describing another example of a procedure, which may be performed by a device, for backscattering signals with power boosting. As shown in FIG. 8, at 810, the device receives a transmission including a signal (e.g., a CW) and/or control information. The control information may include, for example power boosting parameters and repetition parameters, though it should be appreciated that the control information referred to in FIG. 8 may include control information as discussed in any of the embodiments referred to earlier above. As shown at 820, the device determines whether an energy level of the device is sufficient to backscatter the received signal with power boosting.

[0195] The device may backscatter (i.e., reflect) the received signal, while modulating the signal using a parameter based on an energy level of the device. For example, as shown at 830a, if the energy level of the device is sufficient, the device may backscatter the received signal using and modulate the backscattered signal with a preamble using power boosting. Note that in general the device may modulate the backscattered signal with a baseband signal wherein the baseband signal may be a preamble, a data signal, etc. The methods (e.g., methods disclosing power boosting) herein apply similarly to baseband signals other than a preamble. As shown at 830b, if the energy level of the device is not sufficient, the device may backscatter the received signal and modulate the backscattered signal with a preamble multiple times without applying power boosting.

At 840, the device may receive a message (e.g., a reply to the backscattered signal) that includes an indication of a parameter used by the device to modulate the backscattered signal. The indication of the parameter used by the device to modulate the reflected signal may serve as an acknowledgement of the backscattered signal. At 850, the device may send a response to the received reply message including an indication of an identifier and/or an energy level of the device.

[0196] Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

CLAIMS

What is Claimed:

1. A device comprising:

a processor and a transceiver;

the processor and the transceiver configured to receive a transmission including a signal and control information that includes power boosting and repetition parameters;

the processor and the transceiver configured to backscatter the received signal and modulate the backscattered signal with a preamble,

wherein the processor and the transceiver are configured to, on a condition the energy level of the device is sufficient to backscatter the signal with power boosting, backscatter the received signal with power boosting,

and wherein the processor and the transceiver are conditioned to, on a condition the energy level of the device is not sufficient to backscatter the received signal with power boosting, backscatter the received signal and modulate the backscattered signal with a preamble in multiple repetitions without power boosting;

the processor and the transceiver configured to receive a reply message including an indication of the preamble used to modulate the backscattered signal; and

the processor and the transceiver configured to send, in response to the received reply message, information indicating an identifier or an energy level of the device.
2. The device of claim 1, wherein the control information includes an indication to enable or to disable power boosting by the device, an indication of at least a first power level, and an indication of a repetition factor.
3. The device of claim 2, wherein, on the condition the energy level of the device is not sufficient to backscatter the received signal with power boosting, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble in multiple repetitions at the first power level.
4. The device of claim 1, wherein the indication of the preamble used to modulate the backscattered signal is an indication of a cyclic shift of the preamble.
5. The device of claim 1, wherein the control information includes an indication of at least a first preamble length and a second preamble length.
6. The device of claim 5, the processor and the transceiver are configured to use the second preamble length to modulate the backscattered signal based on the reply message including an indication of the preamble used to modulate the backscattered signal is received.

7. The device of claim 1, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a backoff period.

8. The device of claim 1, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a delay.

9. The device of claim 8, wherein the delay is selected randomly from a set of a configured delay values.

10. The device of claim 1, wherein the device is an Internet of Things (IoT) device.

11. A method for backscattering radio frequency (RF) signals, the method comprising:

receiving a transmission including a signal and control information that includes power boosting and repetition parameters;

determining whether an energy level of the device is sufficient to backscatter the signal with power boosting;

on a condition the energy level of the device is sufficient to backscatter the received signal with power boosting, backscattering the received signal and modulating the backscattered signal with a preamble using power boosting;

receiving a reply message including an indication of the preamble used to modulate the backscattered signal; and

sending, in response to the received reply message, information indicating an identifier or an energy level of the device.

12. The method of claim 11, wherein, on a condition the energy level of the device is not sufficient to backscatter the received signal with power boosting, backscattering the received signal and modulating the backscattered signal with a preamble in multiple repetitions without power boosting;

13. The method of claim 12, wherein the power boosting and repetition parameters include an indication to enable or to disable power boosting by the device, an indication of at least a first power level, and an indication of a repetition factor.

14. The method of claim 12, wherein, on the condition the energy level of the device is not sufficient to backscatter the received signal with power boosting, backscatter the received signal and modulate the backscattered signal with a preamble in multiple repetitions at the first power level.

15. The method of claim 11, wherein the indication of the preamble used to modulate the backscattered signal is an indication of a cyclic shift of the preamble.

16. The method of claim 11, wherein the control information includes an indication of at least a first preamble length and a second preamble length.

17. The device of claim 16, the processor and the transceiver are configured to use the second preamble length to modulate the backscattered signal based on whether the reply message including an indication of the preamble used to modulate the backscattered signal is received.

18. The device of claim 11, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a backoff period.

19. The device of claim 11, the processor and the transceiver are configured to backscatter the received signal and modulate the backscattered signal with a preamble after a delay.

20. The device of claim 19, wherein the delay is selected randomly from a set of a configured delay values.

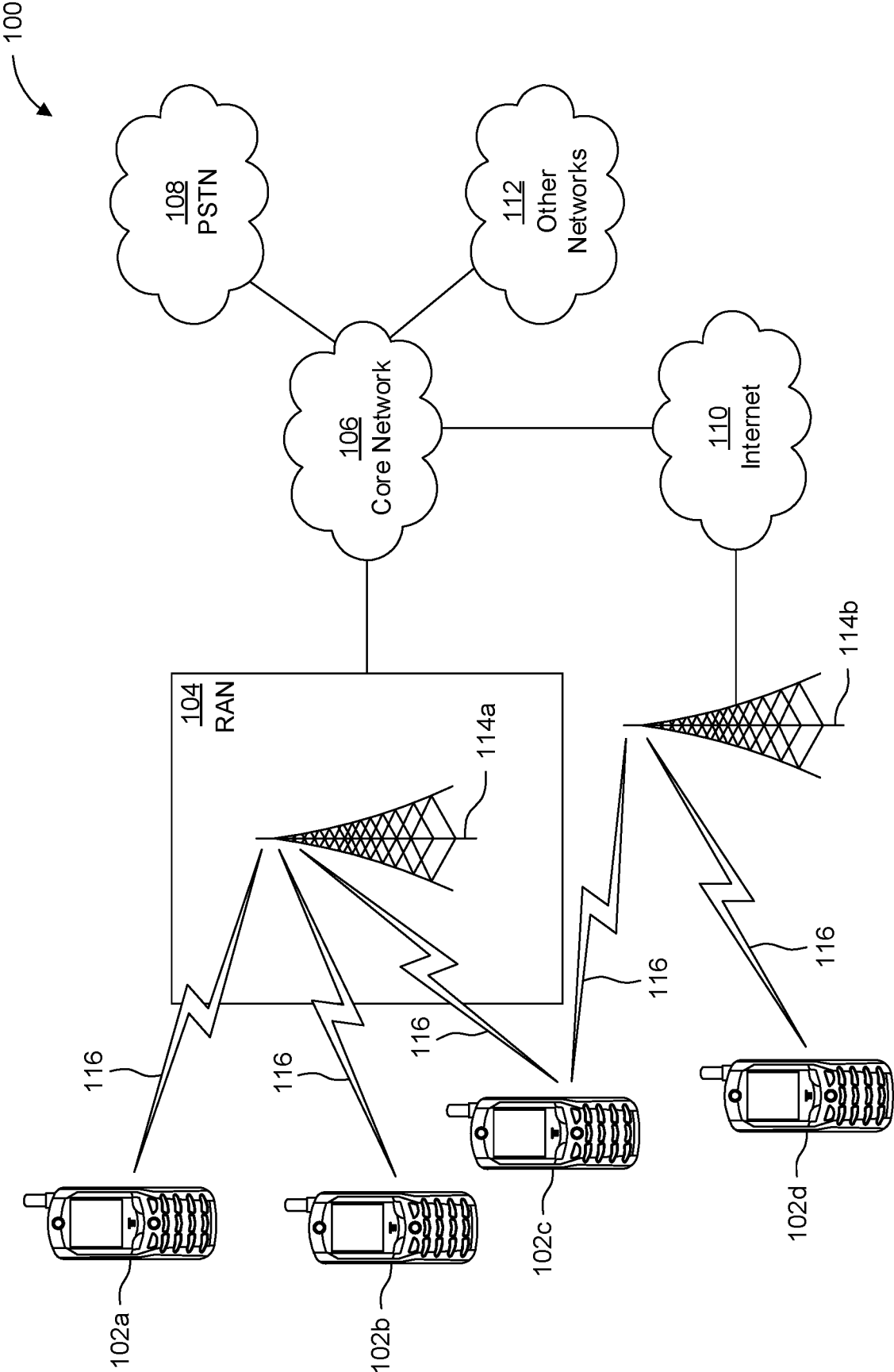


FIG. 1A

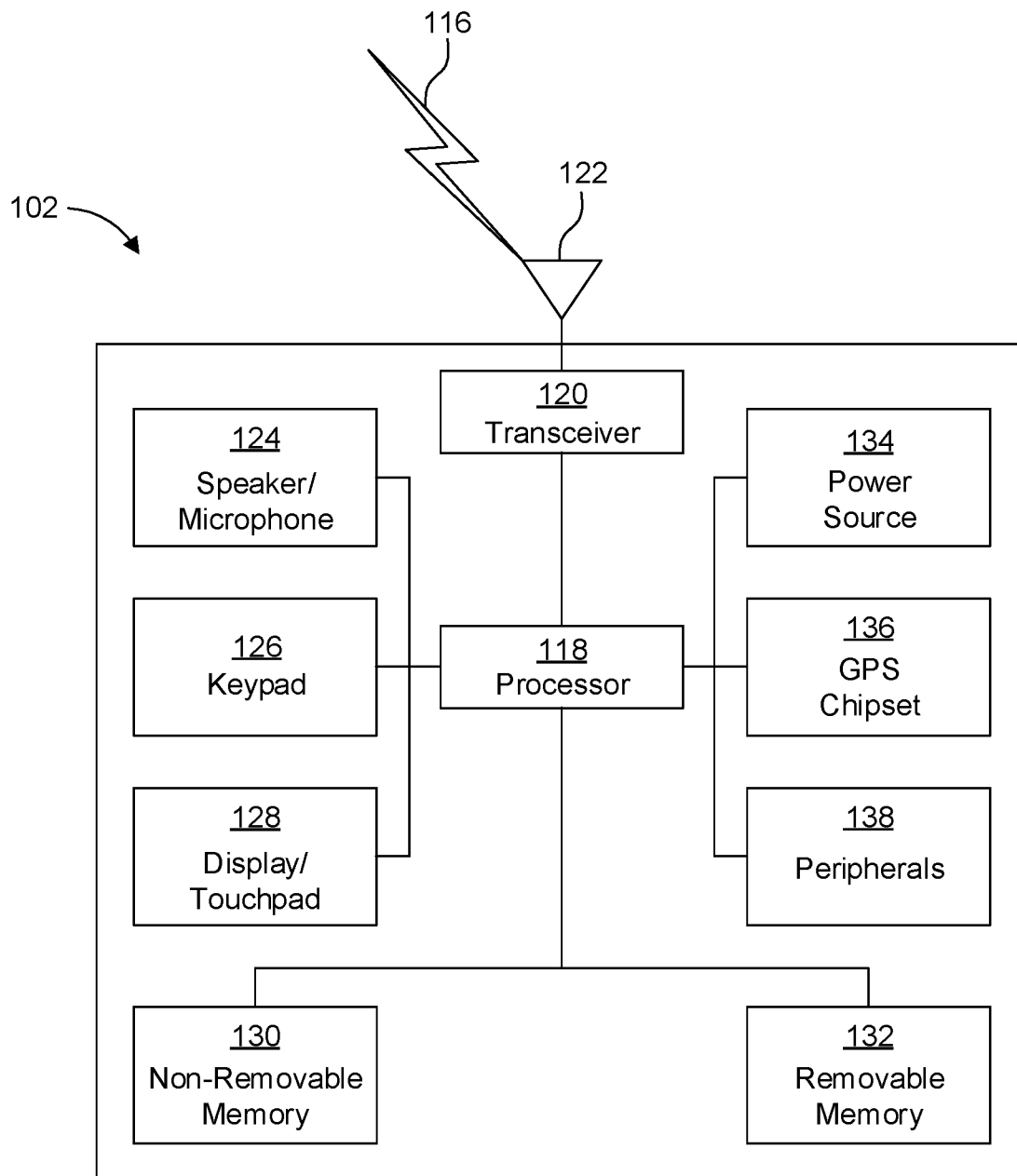


FIG. 1B

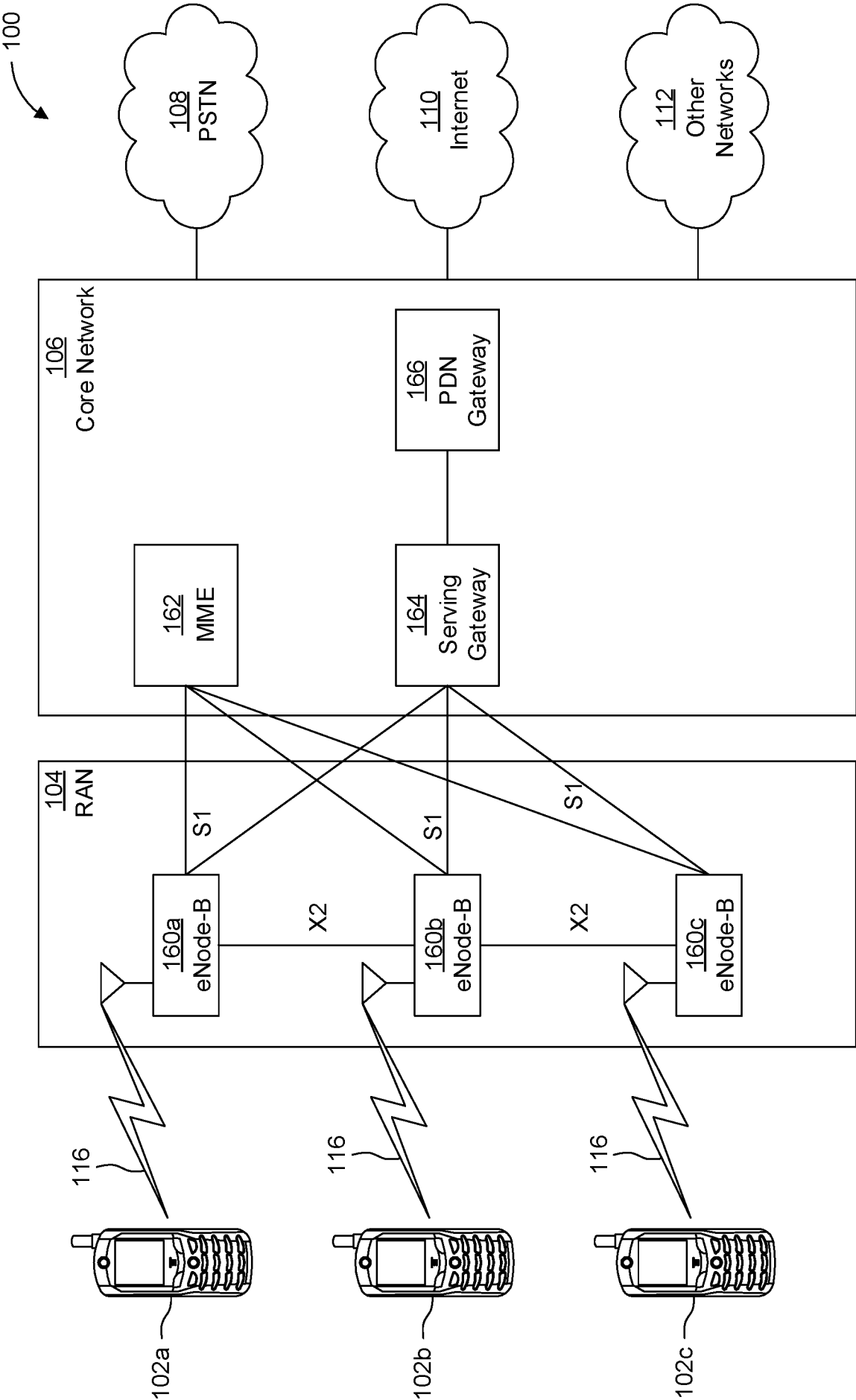


FIG. 1C

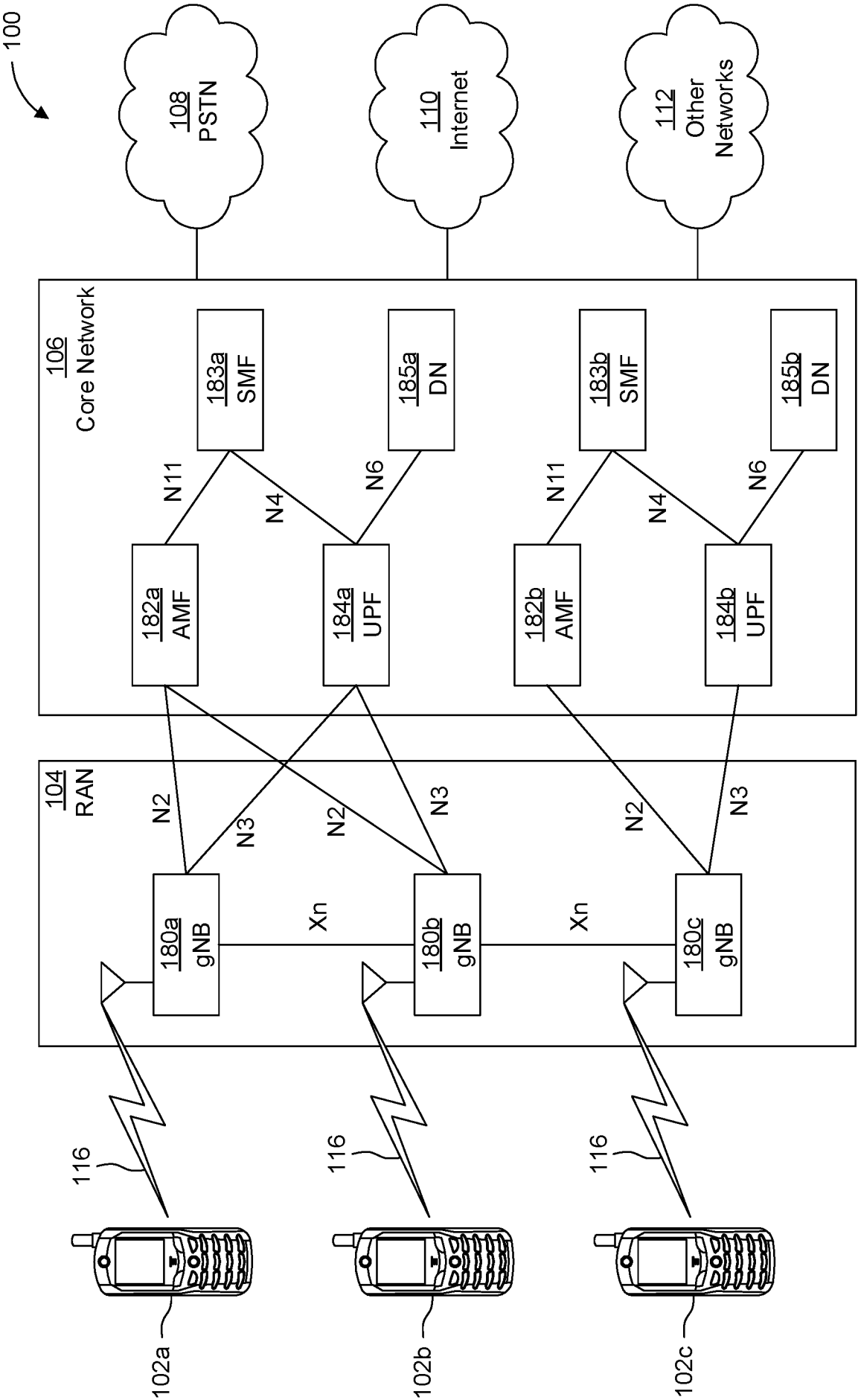


FIG. 1D

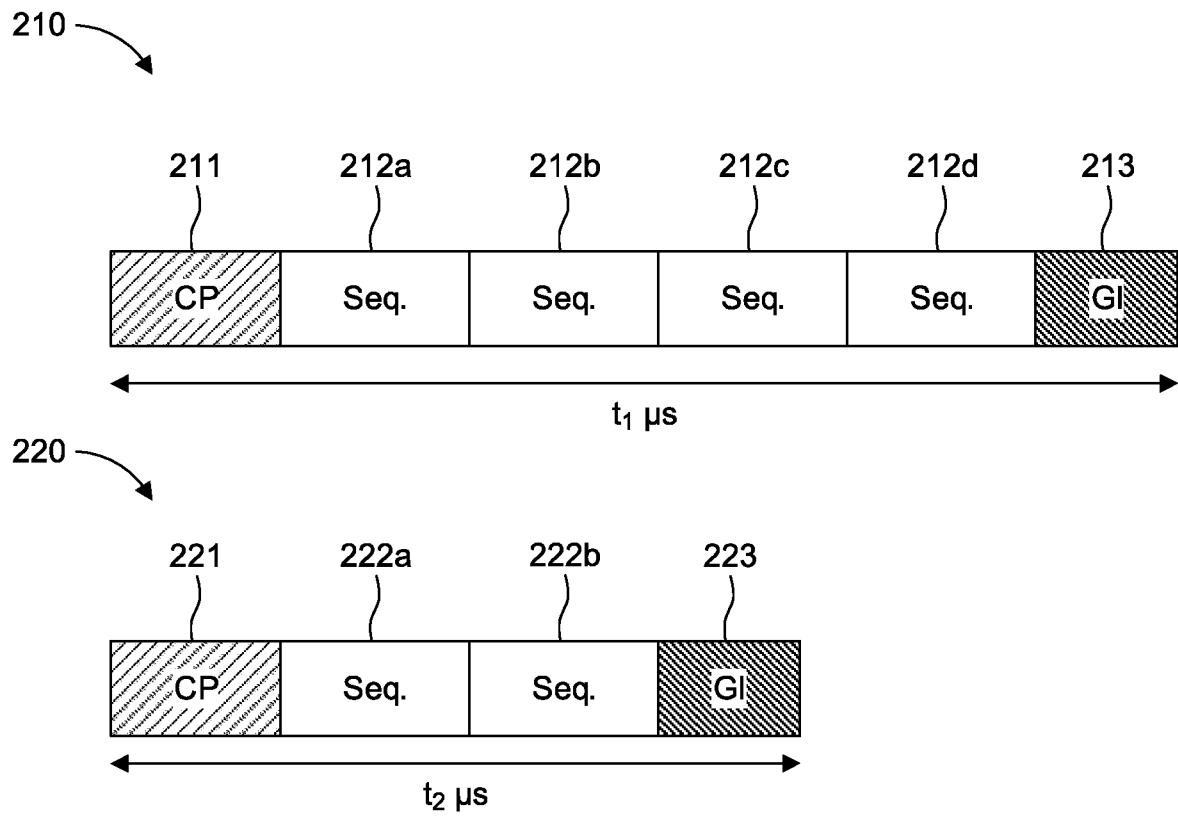


FIG. 2

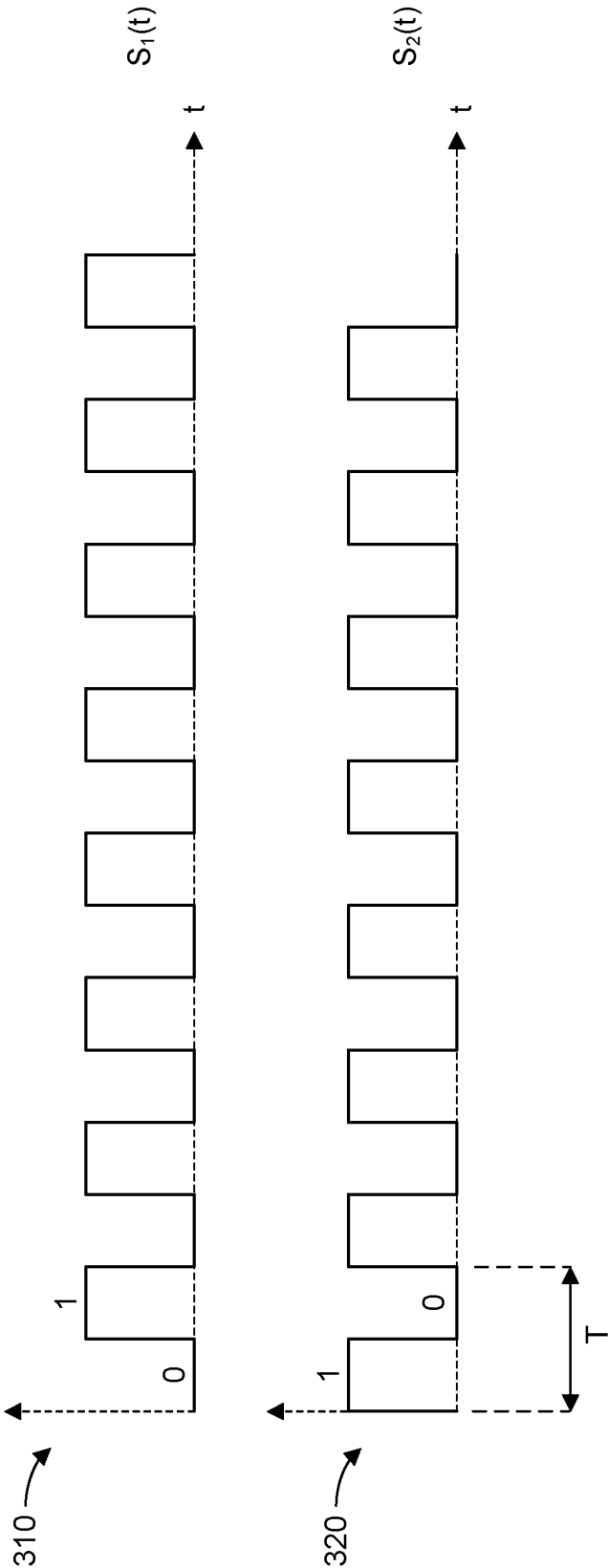


FIG. 3

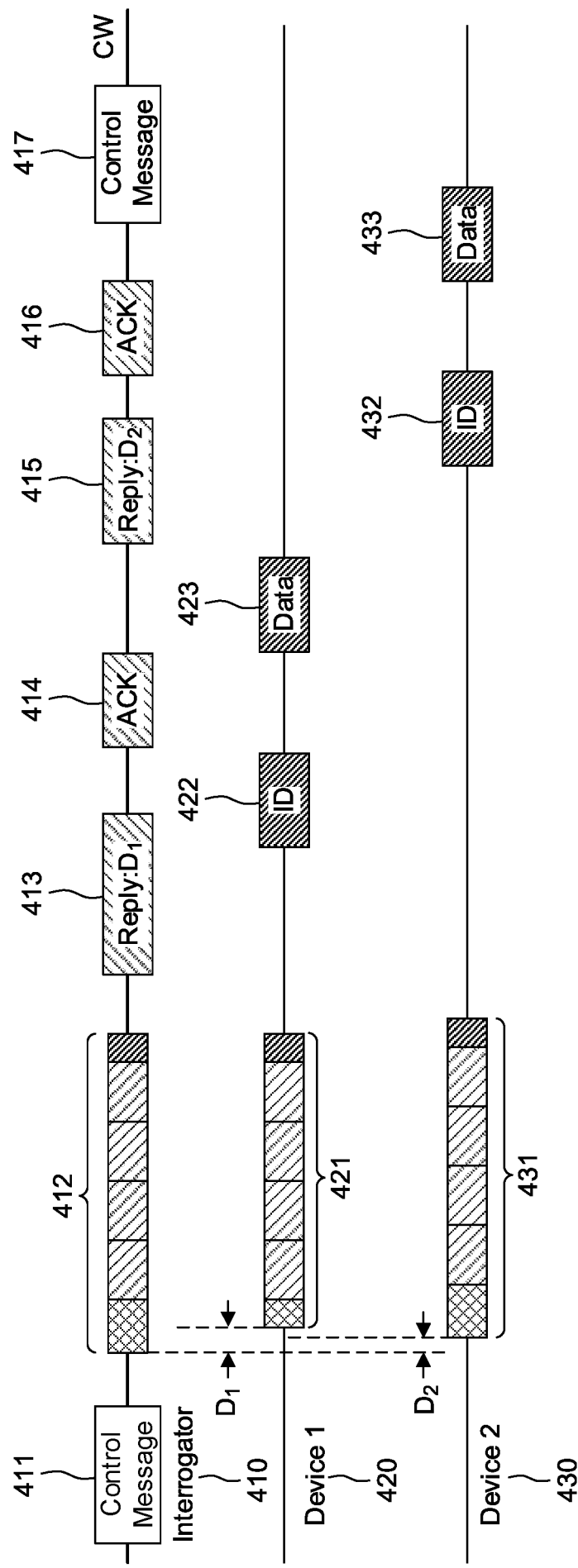


FIG. 4

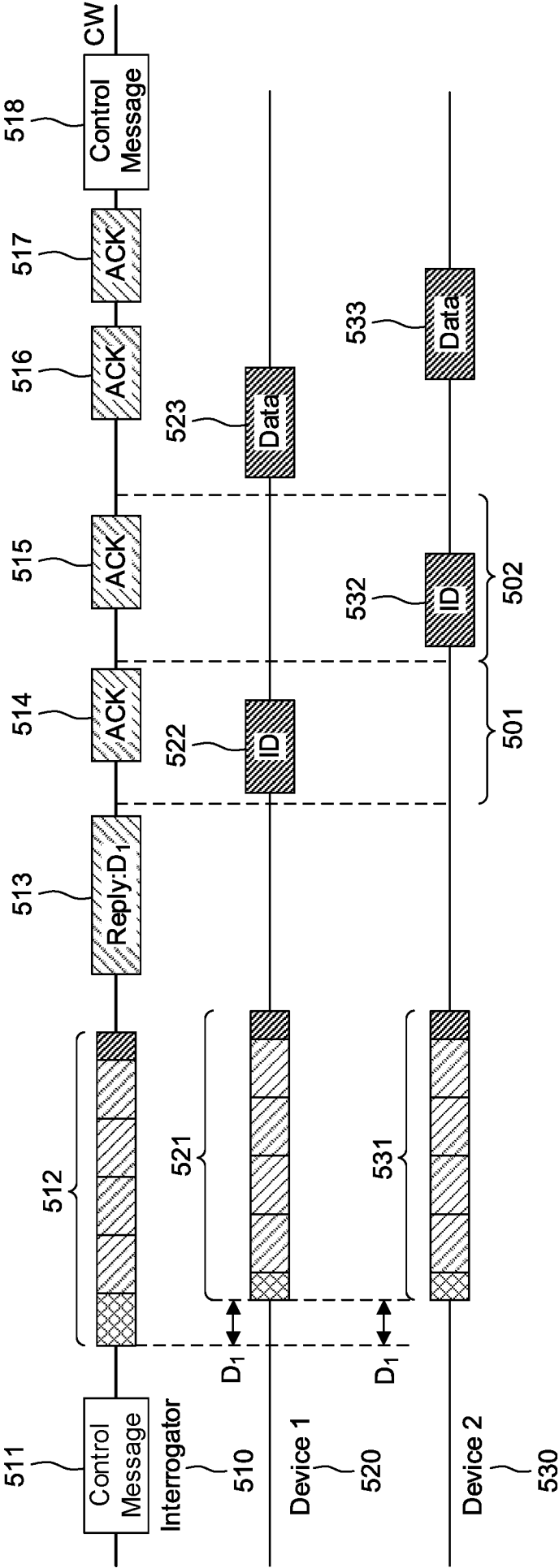


FIG. 5

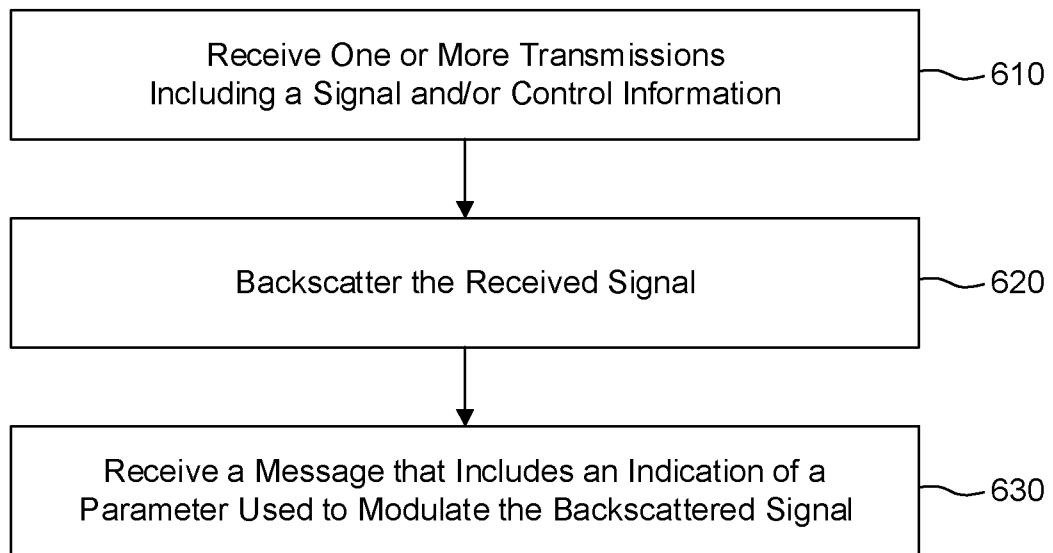


FIG. 6

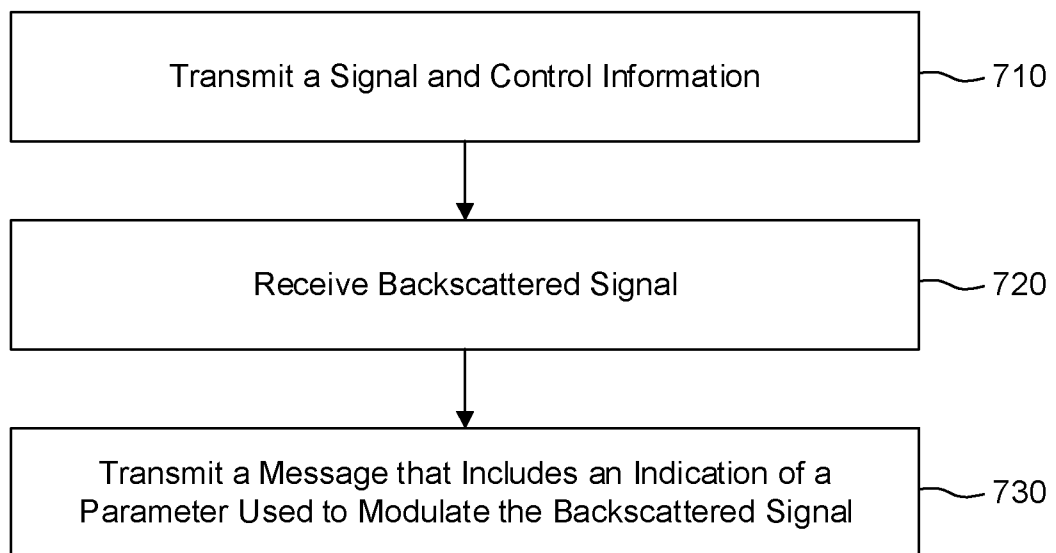


FIG. 7

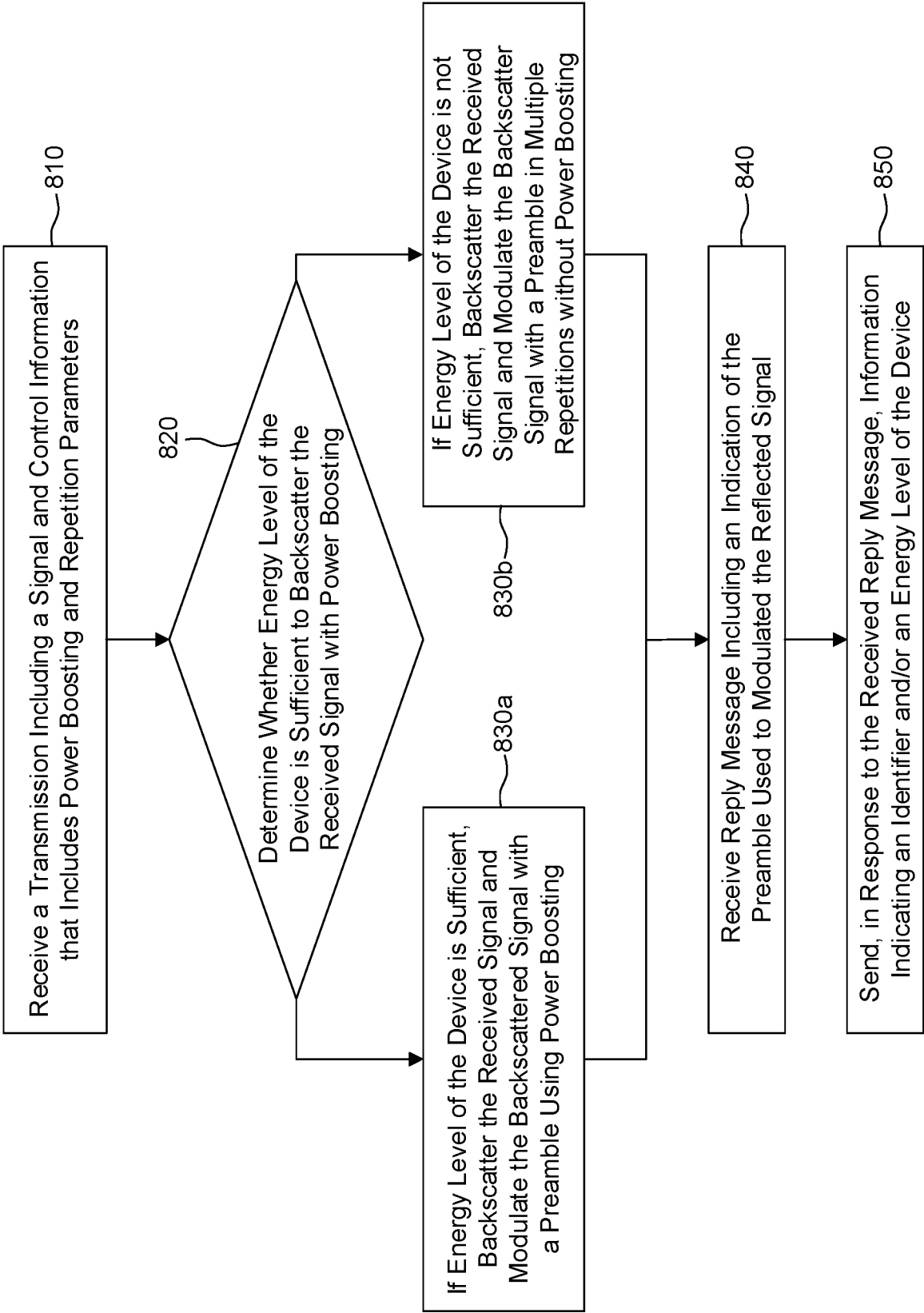


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/041543

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W4/80 H04W52/50

ADD. H04W52/38

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)

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 102 281 036 B1 (RESEARCH & BUSINESS FOUND SUNGKYUNKWAN UNIV [KR]) 23 July 2021 (2021-07-23)	11, 15 - 20
A	paragraphs [0060] - [0068]; figure 3 ----- - / - -	1 - 10, 12 - 14



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

12 November 2024

Date of mailing of the international search report

20/11/2024

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

Tel. (+31-70) 340-2040,

Fax: (+31-70) 340-3016

Authorized officer

Losada Corderí, Iker

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/041543

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	HUAWEI ET AL: "Updated views on Passive IoT", 3GPP DRAFT; RP-212135, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. TSG RAN, no. Electronic Meeting; 20210913 - 20210917 6 September 2021 (2021-09-06), XP052049420, Retrieved from the Internet: URL:https://ftp.3gpp.org/tsg_ran/TSG_RAN/TSGR_93e/Docs/RP-212135.zip RP-212135.doc [retrieved on 2021-09-06] section 2 -----	1 - 20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2024/041543

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 102281036	B1	23-07-2021	NONE
